Towards the Global Virtual Lecture Hall: Case Studies in Global Teaching

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Abstract

The advent of technologies for remote collaboration has led to new developments in work and education during the last few decades, and will continue to profoundly influence working, teaching, and learning in the 21^{st} century. New forms of distance education – MOOCs (Massive Open Online Courses) are just one recent example – make it possible for teachers to reach a large audience, and for students to access educational materials that would not be available to them otherwise. In this thesis the notion of a "Global Virtual Lecture Hall" is proposed to describe a geographically distributed, technology-supported educational environment that allows potentially anyone to participate in an interactive lecture series.

To illustrate the concept of the Global Virtual Lecture Hall, this thesis presents four case studies: The "ShanghAI Lectures" which took place in 2009, 2010, 2011, and 2012. These lectures were a pioneering project in telepresence technology and academic globalization that aimed at preparing students for a global work environment by providing them – as well as lecturers and researchers – with a platform for practicing the effective use of state-of-the-art collaboration technologies. The author of this thesis had been directly involved in this project, first as member of the "core team" in 2009 and subsequently as the overall project coordinator from 2010 to 2012.

This thesis provides a detailed overview of the innovative technical and organizational approaches of the ShanghAI Lectures in general and of the changes that were introduced year-over-year in particular, and investigates and evaluates their outcomes and effects on the project. This gives valuable insight into a highly complex socio-technical system that involved more than 40 universities, institutes, and companies, and reached well over 1000 students around the world.

Finally, a qualitative analysis of the ShanghAI Lectures is presented from the point of view of the involved faculty and staff, from which then properties – success factors and potential challenges – are extracted that contribute to our understanding of how a globally distributed academic community collaboratively enables the emergence of a Global Virtual Lecture Hall and that result in a set of recommendations which may aid anyone who wants to venture into the field of "global education".

Kurzfassung

Die Verbreitung von Technologien zur Zusammenarbeit über grosse Distanzen hat in den letzten Jahren bereits zu neuen Entwicklungen in den Bereichen Arbeit und Bildung geführt und wird auch weiterhin das Arbeiten, Lehren und Lernen im 21. Jahrhundert fundamental beeinflussen. Neue Formen von Fernunterricht – als aktuelles Beispiel mögen etwa die MOOCs (Massive Open Online Courses) dienen – ermöglichen es den Dozierenden, ein grosses Publikum zu erreichen und den Studierenden, auf Unterrichtsmaterialien zuzugreifen, die früher unerreichbar waren. In dieser Dissertation wird der Begriff des «Globalen virtuellen Hörsaals» («Global Virtual Lecture Hall») vorgeschlagen, um eine geographisch verteilte, von Technologie unterstützte Umgebung zu beschreiben, die es potentiell jeder und jedem ermöglicht, an einer interaktiven Vorlesungsreihe teilzunehmen.

Um das Konzept dieses Globalen virtuellen Hörsaals zu illustrieren, werden vier Fallstudien vorgestellt: Die «ShanghAI Lectures» aus den Jahren 2009, 2010, 2011 und 2012. Diese Vorlesungsreihe war ein Pionierprojekt auf den Gebieten der Telepräsenztechnologie und der akademischen Globalisierung, das Studierende für ein globalisiertes Arbeitsumfeld vorbereiten wollte, indem es ihnen – wie auch den Vorlesenden und Forschenden – eine Plattform bot, um effektive Einsatzmöglichkeiten von aktuellen Kollaborationstechnologien kennenzulernen. Der Autor dieser Dissertation war direkt an diesem Projekt beteiligt, zuerst als Mitglied des «Kern-Teams» (2009) und anschliessend als Gesamt-Projektkoordinator von 2010 bis 2012.

Diese Dissertation bietet eine detaillierte Übersicht der innovativen technischen und organisatorischen Ansätze der ShanghAI Lectures im Allgemeinen und der Änderungen, die Jahr für Jahr eingeführt wurden, im Speziellen; dabei werden auch ihre Resultate und Auswirkungen auf das Projekt untersucht und evaluiert. Das gibt einen wertvollen Einblick in ein hochkomplexes soziotechnisches System, das über 40 Universitäten, Institute und Firmen umfasste und weit über 1000 Studierende auf der ganzen Welt erreichte.

Schliesslich wird eine qualitative Analyse der ShanghAI Lectures aus der Sichtweise der beteiligten Vorlesenden und Mitarbeiter präsentiert, aus welcher dann Eigenschaften – Erfolgsfaktoren und mögliche Gefahrenquellen – extrahiert werden, die zu unserem Verständnis beitragen, wie eine global verteilte akademische «Community» die Entstehung des Globalen virtuellen Hörsaals ermöglichen kann. Daraus folgt eine Reihe von Empfehlungen für zukünftige Projekte im Bereich von «global teaching».

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The AI Lab has been "home" to a good number of incredibly talented, creative, and – to various degrees – crazy people whom I am proud to call my colleagues and friends. Shuhei Miyashita invited me to do a small research project together, which resulted in my first conference paper. Thank you for getting me started! Thierry Bücheler, project manager of the original ShanghAI Lectures in 2009, handed over the "project keys" to me (I still have them) – thank you for laying the groundwork and letting me continue this great project! Dana Damian proofread an early version of this thesis, thank you for your valuable input! To everyone else – Alejandro, Claudia, Cristiano, Daniel B., Daniel G., Dorit, Farrukh, Fumiya, Gabriel, Hanspeter, Harold, Helmut, Hidenobu, Hugo, Hung, Jan, Jonas, JuanPi, Kohei, Kojiro, Konstantinos, Lijin, Lukas, Maik, Marc, Martin, Matěj, Max, Miriam, Naveen, Nico, Pascal, Qian, Raja, Ruedi, Simon, Sladjana, Tammy, Tao, Tobias, Verena, …: thanks for being part of the crazy-sexy-cool AI Lab and enriching my stay there in various ways.

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Last but most definitely not least, I thank my parents for their constant encouragement and support, and my wonderful wife for her patience and love.

何源，我亲爱的宝贝，你是我幸福的源!

In short: Big thanks to Rolf and Christopher for pushing me, and to everyone else for *not* pushing me ;-)

Contents

1 Introduction

Globalization and the advent of technologies for remote collaboration have led to new developments in work and education during the last few decades, and will continue to profoundly influence working, teaching, and learning in the 21$^{\text{st}}$ century. As traveling comes under scrutiny (carbon footprint, increasing costs and risks), *virtual collaboration* across national borders is becoming more and more popular. This thesis presents a pioneering project in telepresence [MS97] technology[1] and academic globalization that aims at preparing students for a global work environment by providing them – as well as lecturers and researchers – with a platform for practicing the effective use of state-of-the-art collaboration technologies: The ShanghAI Lectures, a videoconference-based lecture series on Embodied Intelligence, held from 2009 until 2012 with the involvement of more than 40 universities and research institutes around the globe.

This thesis includes a detailed description of this project that has established the notion of a *Global Virtual Lecture Hall*[2] and in which the author had been directly involved, first as member of the "core team" in 2009 and subsequently as the overall project coordinator from 2010 to 2012. These four series of ShanghAI Lectures serve as case studies on how a globally dispersed community of faculty (lecturers, assistants, tutors) and technical staff can collaboratively enable the Global Virtual Lecture Hall.

The most important contribution of this thesis is to understand the mechanics of the ShanghAI Lectures as a complex socio-technical system and to apply this understanding to global teaching by identifying a number of technical, social, institutional, and personal/psychological "success factors" and "potential challenges" that emerge from interviews and surveys with select faculty and staff as well as from personal observations by the author.

Hopefully the outcomes of this investigation (i) encourage lecturers to engage in global teaching activities and (ii) provide a decision aid for educators who potentially enter this field.

1.1 Motivation

The majority of studies in the area of distance education technologies are concerned with the "receiving end" of education, i.e., the *students* [KH09, MW11b, CY12]. To a much lesser

[1] The term "Telepresence" is already over 30 years old – it "was first coined by Marvin Minsky (1980) to emphasize the possibility that human operators could feel the sense of being physically transported to a remote work space via teleoperating systems" [Lee04]. In this thesis, the use of robots in distance education is not investigated, as only recently new developments in robotics had made devices possible that could play a role in this field [KCSEL11].

[2] The author proposes the following definition: *The Global Virtual Lecture Hall is a geographically distributed, technology-supported educational environment that allows potentially anyone to participate in an interactive lecture series.*

degree, *lecturers*' experiences and opinions are investigated in some studies as part of pedagogical considerations, e.g., faculty in [MRH12]. However, the *supporting staff* – assistants, tutors, technicians whose work enables the lecturers and students to participate in the class in the first place – are often neglected, with the exception of studies concerned with pure research collaboration such as [BFS13].

The research focus of this thesis lies therefore on the "giving end" of the lecture series, i.e., the faculty and staff who invest their time and efforts to contribute to the overall success of global teaching, as shown in the ShanghAI Lectures project.

With very few exceptions, students took the ShanghAI Lectures – an introductory course to Embodied Intelligence – only once in their academic career and then moved on to other classes, so there is no cohort data available. As there was no universally applicable set of rules for passing the class at the various participating sites, it is difficult to consistently evaluate the *learning success* of students either – for some, the full course, assignments, and final exam were mandatory to receive credit points, others were not required to participate in the exercises, yet other students joined several weeks after the lecture series had begun (as their local semester dates differ from those of the other sites), and some joined not so much because of the content but out of interest in the technological setup.

That is not to say that it is impossible to do research on the students. In fact, the three-dimensional collaborative virtual environment that was a central part of the ShanghAI Lectures in the first two years served as a research platform for *virtual teamwork* among students [HPZ+09, RH10, Has11] and the *design of three-dimensional spaces* for learning and collaboration [SEG09, SE10, Sch12]. Comparability was limited in the sense that the tasks for students differed between 2009 and 2010, and due to ongoing technical issues with the virtual environment it was eventually replaced by a more feature-rich community website, which limited the scope of the data from the three-dimensional platform to two years.

In contrast to the students, who usually participated for one year only, the group of faculty, assistants, and staff at the individual sites had more continuity. One of the goals of the ShanghAI Lectures project was "to bring people from different backgrounds together, who would not otherwise share common activities" [Pfe10b]. After four years of carrying out this lecture series, with many of the sites participating more than once, the respective persons at these sites can be viewed as "virtual team members" that were brought together to collaboratively enable the ShanghAI Lectures.

Therefore this thesis investigates the "success factors" and "potential challenges" of this educational project as seen by the involved lecturers, assistants, and technical staff, with the overarching research goal:

> **To understand the mechanics of a highly complex socio-technical system in global teaching.**

This understanding is crucial for anyone who wants to venture into global teaching – as a simple example, without a proper understanding of the constraints imposed by the available screen sharing technologies, lecturers may not be able to prepare their slides such that they can be seen by all participants in acceptable quality.

1.2 Method

For this investigation a mixed-method approach is used that includes interviews, surveys, observations, and concepts from both *Grounded theory*[3] and *Action research*[4] applied to the ShanghAI Lectures year after year. Given that the number of respondents (approximately 40) is relatively small compared to the total number of involved faculty and staff (more than 170), it does not make much sense to perform a *statistical* analysis; this investigation is therefore a *qualitative* analysis of factors that have supporting or inhibiting effects on this Global Virtual Lecture Hall.

The data based on which this thesis investigates the Global Virtual Lecture Hall have been collected in the context of four case studies: the ShanghAI Lectures 2009–2012. Case studies are a well suited instrument for such an analytical approach [CMM07], as they "retain the holistic and meaningful characteristics of real-life events" [Yin03] and "involve immersion in one real-life scenario, collecting data of any kind ranging from existing records to ad hoc observations" [Gor12].

1.3 Contributions

The ShanghAI Lectures were held with the goal to making education available to everyone. This thesis aims at *providing an in-depth understanding of this highly complex socio-technical project in global teaching* that combined state-of-the-art technologies – videoconferencing, lecture recording, screen sharing, community websites, three-dimensional collaborative environments, etc. in innovative ways.

The contributions of this thesis and the related work address some of the challenges of organizing and deploying a large-scale educational project that involves lecturers, assistants, and staff from different disciplines, nations, and cultures.

By taking into account the viewpoints of this globally distributed community of faculty and staff, "success factors" and "potential challenges" are identified that contribute to a better understanding of how to plan and implement a Global Virtual Lecture Hall, i.e., an educational environment that allows potentially anyone to participate in an interactive lecture series. Based on these insights, a first set of "Design principles" is presented that may provide a starting point for further research in, and organization of, global educational projects.

As a concrete example of global teaching, the ShanghAI Lectures project has led to a number of practical outcomes, such as an openly accessible lecture repository with well over 100 presentations by high-profile researchers on topics related to "Embodied Artificial Intelligence" (see 3.4.5) or the extension of an open-source three-dimensional framework with capabilities to record the in-world audio and all avatars' movements and actions (see 3.4.6). The ShanghAI Lectures have established a novel way of teaching at roughly a dozen universities around the globe, reaching more than 1000 students. There are already plans to use the

[3]Grounded theory "starts with data, which are then analysed and reviewed to enable the theory to be generated from them" [CMM07], which is the approach used in the analysis of the interview and survey data (see Chapter 4).

[4]Action research, "any research into practice undertaken by those involved in that practice, with an aim to change and improve it" [Coa05], is a popular tool in education and professional development [MW11a, Alb11].

"ShanghAI model" in an EU project and to extend the lecture series with more participating universities.

1.4 Outline

With an overview of technologies that have recently been employed for educational purposes, Chapter 2 provides the "greater context" for the ShanghAI Lectures project, namely, *distance education*. The author's own prior work is described in the second half of this chapter.

This then leads to the detailed description of the ShanghAI Lectures project in Chapter 3, the first of two "cores" of this thesis, where the original goals, technical implementation, and year-over-year improvements are listed together with a first assessment.

The second "core" of this thesis is the evaluation of the ShanghAI Lectures from the point of view of faculty and staff, interspersed with observations by the author and an excursion into concepts from social psychology, which results in the "success factors" and "potential challenges" in Chapter 4.

Chapter 5 concludes this work with a short outlook on the future of the Global Virtual Lecture Hall.

The Appendix contains publications, setup diagrams, lists of the ShanghAI Lectures participants and survey/interview respondents, documents that were sent to the participating sites and guests (which might be of use to educators who potentially venture out into the field of global teaching), and a set of "Design principles for the Global Virtual Lecture Hall".

2 Distance Education: The Landscape

The usage of technologies in higher education is steadily increasing. The first half of this chapter provides an overview of recent developments in such technologies that are related to the ShanghAI Lectures, namely, *videoconferencing*, *lecture repositories*, *course management sites*, *MOOCs*, and *three-dimensional collaborative virtual environments*. While there is no set of features that is common to all the projects presented, there are certain goals or methods that can be compared to the ShanghAI Lectures on an individual basis. In this chapter the similarities and differences are outlined that may help position the ShanghAI Lectures in the landscape of Distance Education.

In the second half of this chapter, the author presents his own related work: The AI Lectures from Tokyo (2003) and the AI Days (2005), two projects that were direct conceptual and technological precursors of the ShanghAI Lectures.

2.1 Introduction

New technologies have often found their way into education and opened up new possibilities for teachers to disseminate and for students to receive knowledge. While the traditional way of teaching – lecturers talk to their students who are assembled in the same place (usually the lecture hall) – is not likely to disappear anytime soon, such teaching/learning environments are constantly extended by introducing new technologies into the classroom. The blackboard could be viewed as an early such technology, more recently replaced, or at least complemented, by the overhead projector, which made it possible for a large audience to see the same text or figures – which then in turn was replaced or complemented by the video projector. In parallel, microphones and loudspeakers enabled acoustic information to reach a larger audience. The nowadays ubiquitous portable computing devices (laptops, smart phones, tablets) and networks allow instant upload and download of knowledge almost anywhere and anytime.

This recent trend to use Information and Communication Technologies (ICT) in education has enabled *real-time participation* by distant audiences. While in earlier times students could follow a class remotely, for example by postal mail, there was no *immediate* form of interaction possible [Hol05]. Modern ICT facilities opened up new ways for large numbers of physically disperse students to follow a class together and even interact with the lecturer(s) and each other – it is thus safe to say that the Internet with all its applications for disseminating and receiving information has started a revolution in education.

A prominent example of this development are *Massive Open Online Classes* (MOOCs), "Internet-based teaching programmes designed to handle thousands of students simultaneously, in part using the tactics of social-networking websites" [Wal13]. While conceptually quite different from the ShanghAI Lectures, MOOCs have the potential to become one (of several) types of a Global Virtual Lecture Hall.

While this thesis focuses only on a small number of ICT facilities in education, the research field is vast. Practical and more general information on ICT usage and impact is available from the pertinent associations and communities, such as *EDUCAUSE*[5] and *eduhub*[6].

2.2 Videoconferencing

Multipoint videoconferencing (see Section 3.1 for a technical description) has been around since the 1960s [VC13], but used in schools for only about 20 years [MPE+13]. In the early years of the new millennium, several projects were deployed or proposed to tackle "global collaboration", such as the *Global Multimedia Collaboration System* in the US [FWU+04] or the *Admire* project in China [JLS04]. These platforms included videoconferencing facilities but had no explicit focus on the delivery of regular lecture series [RS05].

The *Megaconference*[7], which originated at Ohio State University in the US (1999), and its spin-off *Megaconference Jr.*[8] (2002) are the world's largest videoconferences in that everyone with the proper equipment can participate and contribute. As their names imply, they are not lecture series either but rather a sequence of short segments, usually 15 minutes each [Hol08], "on any topic and for any grade range" [Meg13].

One peculiar project is the *Global University System*, an attempt at creating "a satellite/wireless telecommunications infrastructure and educational programmes for access to educational resources across national and cultural boundaries for global peace" [Uts06, RN03].[9]

In contrast, the ShanghAI Lectures focus on one single topic, even though the area of Embodied Artificial Intelligence is large and encompasses many disciplines such as philosophy, biology, electrical engineering, or medicine. The *Megaconference* has a much broader appeal [Hol08], basically, "anything goes". In contrast to the ShanghAI Lectures, which are targeted at university students and take the form of a regular lecture series, the *Megaconference* is basically a showcase of more or less arbitrary videoconference participants, without being embedded in a curriculum and thus without the possibility for students to get credit points.

2.3 Lecture repositories

The Internet contains endless collections of videos, some of which are suitable for, or even targeted at, educational use. As an example, the highly popular video sharing site *Youtube*[10]

[5] `http://www.educause.edu`

[6] `https://www.eduhub.ch`

[7] `http://www.megaconference.org`

[8] `http://megaconferencejr.org`

[9] Curiously, this project seems to have disappeared – there are no publications after 2006, and the project website is only accessible in the "Internet Archive" `http://web.archive.org/web/20121023212843/http://www.friends-partners.org/GLOSAS/`.

[10] `http://www.youtube.com`

(founded in 2005) contains, "in addition to entertainment-oriented content, [...] many serious videos in its Education and Science categories" [TKWP12]. Youtube and similar sites can thus be counted as educational resources [Sne08, Ber09, JC11].

The *Khan Academy*[11] (established in 2006) has goals such as "changing education for better by providing free educational resources to anyone" [CYL+12] and offer thousands of videos covering a variety of subjects. Khan Academy does not want to replace teachers but change their roles – instead of having a monologue, teachers should do "activities that stimulate the brain" in the classroom [Fre13]. While Khan Academy and similar sites undoubtedly have their merits in making educational content easier to access, critical voices note that the pedagogical concept is basically "uncreative, repetitive drilling" [Tho11].

Originating as a conference in 1984 [Hef09], the *TED Talks*[12] came online in 2006. They are often perceived as useful resources for educational content [DR12]; recent bibliometric and webometric data suggests they are used primarily in the general public though, not so much in academia [ST13] – for good reasons, as they do not permit any scientific discourse but are merely presentations of often unvalidated ideas or statements [Rob12].

In recent years, many universities have started to implement their own systems for recording lectures [Bur12]. Usually these platforms are isolated from each other; initiatives like the *SWITCHcollection*[13] in Switzerland that act as a "digital learning repository" of recorded lectures and presentations held at Swiss universities and institutes have recently started to address the need for common platforms, at least on a national level.

While it is probably too ambitious to replace traditional teaching methods by video-recorded lectures, such recordings "may have an important role in reinforcing learning and aiding revision" [SFG10], even though some "educators may be uncomfortable with the fundamental change in the learning process" [CKU08].

Regarding the ShanghAI Lectures there are certain commonalities, e.g., the possibility for students to watch lectures again and again until they feel confident about the topics presented. Most platforms are free yet require a registration for additional functionalities (such as access to online discussion boards). The form of these online classes vary considerably though. For example, typical *Khan Academy* "lectures" are around 10 minutes long and consist of an electronic version of a blackboard that is gradually filled with text, drawings, or formulae, accompanied by the voice of the lecturer; a regular recording from the ShanghAI Lectures lasts 45 minutes and offers a much richer experience: the slides of the lecturer are shown in parallel to the speaker (who is usually displayed in the context of the videoconference, i.e., other participating sites are visible as well), and sometimes short videos are shown to illustrate certain concepts. The ShanghAI Lectures are much closer to a traditional lecture with multiple concurrent "channels" (lecturer, slides, interaction with audience).

Many lecture repositories rely on Youtube as the technical framework for hosting the videos and potentially other social media such as Facebook, Twitter, or Google+ for additional functionality. However, while "social media in education" certainly sounds very ap-

[11] `http://www.khanacademy.org`

[12] `http://www.ted.com`

[13] `https://collection.switch.ch`; the ShanghAI Lectures recordings are also hosted there.

pealing, especially to an European or US-centric audience, many Internet services are not available on a truly global scale. For example, access to Youtube, Twitter, and Google has been blocked or at least heavily restricted in mainland China in the last few years[14]. For some lecture repositories like the *Khan Academy*, solutions had to be set up that involve a country's local (and officially approved) video hosting services [Kha11]. The ShanghAI Lectures are hosted on the SWITCHcast system which has no known restrictions in that regard, so the recorded talks are indeed available on a global scale. The Twitter account used during the ShanghAI Lectures only served as an additional "distribution channel" of news items that were posted on the project website anyway, i.e., no essential information were withheld from those without Twitter access.

2.4 Web-based educational management systems

Connecting and integrating previously independent, local databases, networks, services, and management tools – such as systems for student administration, document repositories, calendars, and communication facilities, e.g., forums, web-based chat – led to a large number of online systems specifically tailored towards the needs of educators. The umbrella term for these frameworks, which automate "the administration, tracking, and reporting of training events" [Ell09], is *Learning Management Systems* (LMS). Well-known examples of LMS are *WebCT/Blackboard*[15] (1995), *OLAT*[16] (1999), *Moodle*[17] (2002), or *Sakai*[18] (2005).

Course Management Systems (CMS) provide a subset of functions of an LMS. In particular, a CMS is "used primarily for online or blended learning, supporting the placement of course materials online, associating students with courses, tracking student performance, storing student submissions and mediating communication between the students as well as their instructor" [WW07].

After failed attempts by "many prestigious American universities" to capitalize on selling their knowledge on the Internet [SC06], the Massachusetts Institute of Technology in 2001 announced the OpenCourseWare initiative: Educational packages consisting of lecture videos, handouts, quizzes for self-assessment, and homework with sample solutions. There is no or not much interaction with the lecturer, and the courses usually do not yield any credits, though in 2012 MIT has announced a new initiative, *MITx*[19] that allows students to communicate with their peers; students who finish the course receive a certificate[20] [Are12, Cro11].

[14] First-hand experience of the author of this thesis; while traveling in China he relied on a VPN connection to his home university to use "Western" social media.

[15] `http://www.blackboard.com`

[16] `http://www.olat.org`

[17] `https://moodle.org`

[18] `http://www.sakaiproject.org`

[19] `http://www.mitx.org`

[20] "The certificate will obviously not carry the weight of a traditional M.I.T. diploma, but it will provide an incentive to finish the online material." [Cro11]

2.5 MOOCs

In the last few years, a new phenomenon in higher education has emerged: *Massive Open Online Courses* (MOOCs), which could be understood as the combination of course management systems and lecture repositories where the recorded lectures are segmented into small chunks with short quizzes placed in-between that control the flow of the lecture (the next segment is only accessible upon successful completion of the quiz). There are no live broadcasts of the lectures, and interaction between students and lecturers is quite limited.

While the term "MOOC" was coined in 2008 [Hil12], the underlying ideas date back to "at least the 1990s" [Wal13]. With Sebastian Thrun's *AI Class*[21] in 2011, MOOCs made their grand entry not only in the circles of educators, but also in the general public. Since then, several companies started to push MOOCs forward (Udacity, Coursera, and edX to name but a few), though it remains to be seen how much of an impact on "traditional" higher education systems worldwide MOOCs will have, especially since the drop-out rate of MOOCs is very high compared to traditional courses [Hil12, BT13, Fre13], and there are rather voiced concerns, e.g., about the absence of pedagogical concepts and about the socio-economical impact of MOOCs [Var12].

MOOCs and the ShanghAI Lectures have quite similar objectives – mainly, making education available to a global audience and providing their content in the form of university lectures –, yet follow very different paths to reach these goals. While the ShanghAI Lectures focus on the *interaction* between the lecturers and the audience (during the live videoconference, anyone can raise their hand and ask questions, and there are discussion sessions after every guest lecture) to give the participants the feeling of sitting in a "regular" classroom, MOOCs consist of pre-recorded short clips of the lecturer that are interrupted by a quiz every few minutes and intended to be "consumed" by individuals.

Registration numbers of typical MOOCs reach tens of thousands of participants; however, completion rates "rarely rise above 15%" [Wal13]. In the ShanghAI Lectures, there are some hundreds of students participating every year, and most of them complete the course[22]. The fact that the ShanghAI Lectures are held live, to be attended in a *physical* lecture room at the participating universities, together with one's peers, at *fixed* dates and times, just like a regular, locally-held course, already filters out students who are not willing or able to keep a certain level of commitment during the semester. MOOCs can be followed from anywhere and at any time and – unless one wants to get some kind of "certificate of completion" – do not require much effort, and there is no penalty for quietly abandoning the course.

There were a number of "external viewers" in the ShanghAI Lectures, i.e., individuals who were not enrolled at any of the 12–15 universities that joined the weekly videoconference and thus followed the course only by watching the recorded lectures, but the author of this

[21] `https://www.ai-class.com` – It is a curious coincidence that this is also a course on Artificial Intelligence, albeit more focused on "traditional", non-embodied AI – machine learning, planning, computer vision, language processing – and geared towards concrete applications, whereas the ShanghAI Lectures are all about the "embodied" approaches in AI and provide a new way of thinking.

[22] Due to the distributed nature of the ShanghAI Lectures where every participating university has their own rules for completion and grading, the only comparable data are the number of registered students who participate in the group exercises.

thesis knows of only one person who also *actively participated* in the group exercises and asked for a confirmation that she completed the course. The majority of "external viewers" just followed the lecture series passively, which seems to correspond with the situation in MOOCs.

2.6 3-Dimensional Collaborative Virtual Environments

The basic working principle of virtual worlds is that users log in as "avatars" (virtual embodied representations of themselves) from anywhere they like, provided the infrastructure, i.e., bandwidth and hardware equipment, is sufficient, and interact with others in a three-dimensional, fully configurable space, the *Collaborative Virtual Environment* (CVE). In contrast to videoconferencing, 3-D CVEs enable a variety of interaction possibilities. For example, the appearance of a users' virtual embodiment and the abilities to move the avatar's body parts and to navigate can be used as a non-verbal communication channel in parallel to voice and text chat, and interactive objects in the virtual environment can support and foster collaboration tasks and make work and learning in virtual worlds more motivating and engaging. Research has further shown that the visual character of virtual worlds increases memorability and retention [SEG09].

Very early examples of virtual worlds as technologies for distance education include *Shared-ARK* [Smi92] and the *Intelligent Distributed Virtual Training Environment (INVITE)*[23] [BHTT01] which, however, were only prototypes and did not result in actual products. Today there are a vast number of 3-D CVEs both for educational and commercial use; a recent overview counted about 90 platforms [SAa12].

Some of these environments are theoretically infinitely large as servers can be "federated" (i.e., connected such that the respective environments become mutually accessible), others are "closed" in that there is no possibility to "travel" from one server to another.

3-D CVEs have been found to be particularly useful tools to implement what is called *authentic learning*[24] that focuses on "real-world, complex problems and their solutions, using role-playing exercises, problem-based activities, case studies, and participation in virtual communities of practice" [Lom07, KR08], and they offer ways of interaction that convey "a sense of presence lacking in other media" [New07].

2.6.1 Commercial 3-D CVEs

Commercial virtual worlds, such as *Active Worlds*[25] (1995) and *Second Life*[26] (2002), which were mainly targeted at entertainment, are also increasingly being used in educational projects [Wye11], for example in the "Terra Incognita" project of the University of Southern Queensland in Australia and in "CyberOne" at Harvard Law School [BA08]. Commercial CVEs are

[23] `http://invite.fh-joanneum.at`, though this website seems to be offline (last check: 2013-05-28).
[24] In essence, it is the same as "Learning by doing".
[25] `http://www.activeworlds.com`
[26] `http://secondlife.com`

costly though: for example, Second Life charges hundreds of dollars for monthly maintenance [KR08]. A recent increase of the fee for educational institutions has led many schools and universities to abandon Second Life and move to open source CVEs instead [Kor11a].

Commercial 3-D CVEs usually do not allow access to usage or log data, and as with video repositories there are still open questions regarding copyright and licencing of user-generated content, especially in multinational projects. Additionally, some feature-rich 3-D CVEs are only popular in certain countries: for example, in China the local *HiPiHi*[27] platform dominates the market while Second Life is not popular at all [ZCVZ09].

2.6.2 Open source 3-D CVEs

Four 3-D CVEs are available as open source frameworks, all of which have already been used in educational projects despite the fact that they are all still under development.

OpenSim [28] (2007), written in C, is establishing itself as the open source "successor" of Second Life – it supports the same protocols, and transferring content from Second Life to OpenSim is relatively easy.

realXtend [29] (2008), written in C++ and Python, started as an extension of the OpenSim platform and has, due to its architecture [Ala11], a lot of potential to become the most powerful open source 3-D CVE; however, until it becomes a viable alternative to commercial systems it still "has a long way to go"[30].

OpenQwaq [31] (2011) emerged from the commercial *Teleplace* framework [Kor11c]; Teleplace was shut down shortly after releasing a first open source version of its core asset [Kor11b]. OpenQwaq is written in Squeak, a variant of Smalltalk, which is a rather "exotic" language compared to those used for the other open source 3-D CVEs. However, OpenQwaq is very powerful in terms of functionality, e.g., it provides facilities for in-world editing of text and spreadsheet documents.

Open Wonderland [32] (2007), written in Java, was used in the ShanghAI Lectures and will be described in chapter 3.4.6.

2.7 Global university projects

The last ten years saw the emergence of many educational projects that combined technologies in novel ways; the predominant term in the literature is "Virtual Meetings" [EDU06],

[27] `http://www.hipihi.com/index_english.html`
[28] `http://opensimulator.org`
[29] `http://realxtend.org`
[30] Ilan Tochner, personal communication (2012-03-29). Ilan Tochner is Co-Founder and CEO of the on-demand virtual world hosting service *Kitely* that currently uses OpenSim: `http://www.kitely.com`
[31] `https://code.google.com/p/openqwaq`
[32] `http://openwonderland.org`

for example, the *Cross-Cultural Rhetoric Project* at Stanford[33] which employed "video conferences, collaborative blogs, writing on a Wiki, and dynamic chat" [OE08].

In the context of a plea for an international federation of education networks, a "virtual Global University" is suggested that addresses "challenging global questions" such as environmental sustainability, international jurisdiction, or the research and treatment of diseases using "course management systems, tele/videoconferencing, online digital archives, and even shared open-software administrative systems" [Mit06] – the only technical component that separates this (fictitious) project from the (real) ShanghAI Lectures is a 3-D CVE.

2.8 Own work

The author of this thesis had the chance to gain hands-on experience with two global teaching projects at the AI Lab[34] (Artificial Intelligence Laboratory, Department of Informatics at the University of Zurich), that can be seen as direct "ancestors" to the ShanghAI Lectures: First as an assistant in the AI Lectures from Tokyo (2003), then as the coordinator of the AI Days (2005).

2.8.1 The AI Lectures from Tokyo[35]

In the past, the Department of Informatics at the University of Zurich offered an introductory course in Computer Science for all faculties. The final class in this series was traditionally organized as a special "Christmas lecture" with surprises for the students (and sometimes also for the lecturers). In December 2002, while Rolf Pfeifer was visiting the University of Tokyo, he connected to the Christmas lecture via videoconference, while his colleague Helmut Schauer was "moderating" locally in Zurich. This experiment, despite some technical issues, proved to be very popular with the students[36] and was considered a "great success"[37].

As Rolf Pfeifer was going to spend his sabbatical at the University of Tokyo during the winter term of 2003/2004, but still wanted to teach his own class "Introduction to Artificial Intelligence" to students in Zurich, an entire videoconference-held lecture series was organized between Tokyo and Zurich. To make this enterprise more attractive, other universities that already had some form of collaboration with the AI Lab in Zurich were included as well, namely:

- University of Tokyo, Japan
- Peking University, Beijing, China
- Polish-Japanese Institute of Information Technology, Warsaw, Poland
- Ludwig Maximilian University and Technical University Munich, Germany

[33] `http://ccr.stanford.edu/project.html`
[34] Of which Rolf Pfeifer, the supervisor of this thesis, is the director.
[35] This section is loosely based on [Lab04a]
[36] personal recollection of the author of this thesis
[37] Rolf Pfeifer, personal communication (2013-05-20)

- Technical University of Lodz, Poland
- King Abdulaziz University, Jeddah, Saudi Arabia

The AI Lectures from Tokyo started on 4 November 2003 and lasted for ten weeks. The first eight lectures were held by Rolf Pfeifer, based on his book *"Understanding Intelligence"* [PS99]; the remaining two classes were titled "The Latest from Japan" and "Future Trends" and featured guest presentations by Japanese researchers as well as scientists from other participating sites.

The AI Lectures from Tokyo were the first multipoint videoconference lecture series held at the University of Zurich [Enz04]. SWITCH, the Swiss Education and Research Network[38], supported the project with their infrastructure, expertise, and help throughout the planning and deployment phase, for example by hosting the videoconference [D'A03]. In addition to the videoconference connection, the computer screens (e.g., for Powerpoint presentations) were shared among the participating sites using the *BridgIt*[39] software which was provided by the Multimedia Services of the University of Zurich. To enable technical staff at the various sites to communicate "in the background" without interrupting the flow of the lecture, a popular chat program was used. This setup with three channels – videoconferencing, screen sharing, and chat – proved to be so useful that it was kept, with only minor alterations, for future videoconference events such as the AI Days (see next section) and eventually the ShanghAI Lectures.

A core aspect of the AI Lectures from Tokyo was to create a community of the involved students, lecturers, and researchers from the seven sites. To this end, the participating institutions were invited to introduce themselves at the beginning of one lecture, so that all sites would get a better idea of each other. To make the lectures more interactive, the lecturer prepared questions (e.g., showing a video of robots and then asking one site to describe what the robots were doing), and students were asked to give short presentations about certain topics, e.g., the *Frame Problem*[40], the *Chinese Room*[41], or *Artificial Evolution as a tool for Automated Design* [PS99]. A website[42] was set up where students could register to access reading materials, such as selected chapters from the textbook, watch the lecture recordings, and communicate with each other [Kra04]. Such a "community website" would also be a central part of the ShanghAI Lectures several years later.

To reach a large audience, the lectures were streamed live, recorded, and made available on the project website. Both recording and streaming were done using the *PLAY* system, a

[38] `https://www.switch.ch`

[39] `http://smarttech.com/bridgit`

[40] The "Frame Problem" is concerned with how a representation or model of the environment can be kept up to date with the real world (which is constantly changing).

[41] In this thought experiment by John Searle, a person – who does not understand Chinese – sits in a room and receives sheets of paper with Chinese characters on them (e.g., questions – though the person does not know what the symbols mean). The room is full of books with rules that tell the person how to process the symbols and write the results (answers), which he then hands out again. Where is the "understanding" of Chinese located – in the books? In the room? Is there any understanding at all if one simply follows "mechanical" rules? [Sea80]

[42] `http://tokyolectures.org`

joint development by ETH Zurich and Solutionpark[43] which captured, synchronized, and broadcast the videoconferencing and screen sharing channels in a semi-automatic way (the slides in the screen sharing channel had to be captured manually). Worldwide distribution of the data stream was handled by the *Akamai*[44] network. After each lecture, the recording was edited (e.g., chapter markers were added and in one case, copyrighted material had to be masked) and then published on the website both as streaming video-on-demand and as a downloadable movie file.

Roughly 1000 people registered on the TokyoLectures website. Of those, 94 participated in a survey at the end of the semester, which resulted in a very high satisfaction rate: on a five-step Likert scale, roughly 85% agreed or strongly agreed that this kind of lecture series should be continued, and 70% suggested or strongly suggested to apply such a lecture style to other courses as well [Lab04a, Lab04b]. Detailed measurements on how many viewers followed the course via live stream or recordings are not available anymore; however, for one lecture (on "Evolution") about 16'000 downloads were registered[45]. Many of the involved speakers and institutes asked for a follow-up event, which led to the AI Days (see next section). Eventually the AI Lectures from Tokyo found their successor in the ShanghAI Lectures series.

In short, the AI Lectures from Tokyo represented the state of the art in global teaching at the University of Zurich in 2003, predating the ShanghAI Lectures by roughly six years but already defining some of their core components: a community website, interactive multipoint videoconference with separate channels for audio/video and slides, a background communication system, and a repository of the recorded lectures.

2.8.2 The AI Days[46]

Instead of simply duplicating the AI Lectures from Tokyo with five to seven videoconference participants in a weekly lecture series, the AI Days consisted of two full-day videoconference events held on 14 and 21 December 2005. The idea was not to give a lecture to students but rather to provide an experimental platform for "global connectivity" where scientists or institutes around the planet could try out videoconferencing technology and at the same time showcase their research to a world-wide audience, similar to the Megaconference (mentioned in 2.2 above) and the "Latest from Japan" or "Future Trends" sessions in the AI Lectures from Tokyo.

Each AI Day lasted from 09:00–18:00 CET and was segmented into 10 to 12 slots, which were structured as follows:

- short introduction by the moderator, making sure audio/video and screensharing connections were fine

[43] This company was a spin-off of ETH Zurich and has in the meantime been acquired by Swisscom, the largest telecommunications company in Switzerland.

[44] `http://www.akamai.com`

[45] Rolf Pfeifer, personal communication (2013-01-25)

[46] This section is loosely based on [Lab06]

- presentation by the participating site, preferrably live (it was also possible to submit a prerecorded video that would be played in the videoconference)
- live discussion or Question & Answer session with all sites
- short break during which sites could disconnect or join the videoconference

All these presentations were streamed live[47], recorded, and published on the project website[48]. The technological infrastructure was basically the same as with the AI Lectures from Tokyo, i.e, the videoconference and slides were kept in separate channels. The fact that the AI Days lasted an entire working day and posed virtually no restrictions on the participants resulted in a variety of presentations, for example jumping robots from Japan, Austrian students' Lego Mindstorm creations, a portrait of Dar Al-Hekma College in Saudi Arabia, and artists from the US and Japan presenting their takes on Artificial Intelligence.

2.9 Conclusions

In the first decade of the new millennium, technological developments made substantial advances and became increasingly interesting for the educational sector: High-speed networks, multipoint videoconferencing, virtual meetings, video repositories, course management systems, and three-dimensional environments became more and more attractive to universities. In short, the technologies were there and the time was right for novel approaches to education on a global scale (Figure 2.1).

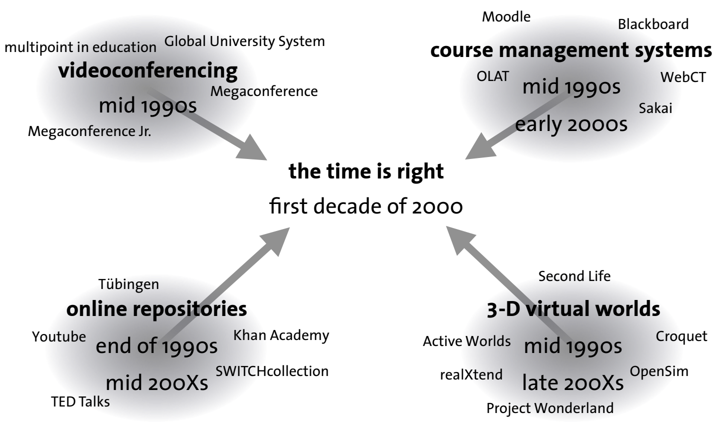


Figure 2.1: Technological context of the ShanghAI Lectures.

[47] This time without Akamai, as the online audience was not expected to be as large as with the AI Lectures from Tokyo.

[48] `http://tokyolectures.org/ai-days` – due to server issues, this directory was lost when moving the virtual server to another machine; Hanspeter Kunz, personal communication (2012-08-21).

3 Research Context: The ShanghAI Lectures

This chapter is partially based on the publications [Lab10], [LH11] (see Appendix B), and [LHZS12] (see Appendix C).

The Artificial Intelligence Laboratory at the Department of Informatics, University of Zurich, presented a global lecture series on natural and artificial intelligence, each fall term from 2009 until 2012. This course was based on the textbook *"How the Body Shapes the Way We Think – A New View of Intelligence"* [PB07] and introduced the notion of "Embodiment", a concept which studies the role of the body in the development of intelligent behavior and that has implications beyond robotics, artificial intelligence, behavioral and neuroscience. The lectures were therefore designed for a broad interdisciplinary audience and not just for computer scientists.

Called the "ShanghAI Lectures", this educational project was initially planned as a one-semester event; since many of the participating sites voiced their interest in a continuation of this series, ShanghAI Lectures were held again in the following three years, each time with some changes to the overall concept and technologies. These technologies, as well as their intended purposes and actual outcomes, are outlined in this Chapter.

Through their novel use of technologies, the ShanghAI Lectures served as a research platform for virtual team behavior, crowdsourcing, and global teaching. The project was managed by Thierry Bücheler [Büc12] in 2009 and by the author of this thesis in the years that followed.

3.1 Origins

The translation of the above-mentioned textbook into Chinese[49] was completed in 2009 by a team at Shanghai Jiao Tong University (SJTU) in China. To accompany the launch of the Chinese edition, and to promote SJTU as an important venue for robotics and embodied intelligence, a lecture series was organized in the style of the AI Lectures from Tokyo with about twice as many participating sites (between 12 and 15 universities joined the videoconference every week) and more guest lectures by renowned researchers from around the world. In addition, to foster interactivity among the participating students, and to perform research on virtual team behavior, group exercises were set up in a three-dimensional collaborative virtual environment.

[49] 身体的智能 -- 智能科学新视角 (*Shēntǐ de zhìnéng – zhìnéng kēxué xīn shìjiǎo, "Body Intelligence – a new perspective on the science of intelligence"*) [PBY+09]

3.2 Goals and means

The ShanghAI Lectures set out with a multitude of (partially overlapping) educational, social, technical, and research-oriented goals:

Educational goals: Making education and knowledge on cutting-edge scientific topics accessible to everyone; familiarizing students with technologies that might be relevant to them in their professional life (e.g., three-dimensional collaborative virtual environments); "spreading the word" of the concept of "Embodiment"; and bringing global teaching to a new level by overcoming the complexity of a multi-cultural and interdisciplinary learning context.

Social goals: Creating a "sense of presence" for the lecturers and students during the live classes and sessions in the virtual environment; fostering intercultural collaboration among students and researchers from around the globe; and building a sustainable community of students and researchers in the area of Embodied Intelligence.

Technical goals: Exploring novel technologies for educational purposes and knowledge transfer, such as allowing viewers to annotate the recorded lectures [HPZ+09]; experimenting with three-dimensional collaborative virtual environments; and integrating technologies (such as videoconferencing, lecture recording, and web-based collaboration facilities) in novel ways to enable global teaching.

Research goals: Conducting studies on the behavior of "virtual teams" [HBP09] under special consideration of cultural diversity [Has10]; crowdsourcing [Büc12]; and global teaching (this dissertation).

In order to reach these goals, a number of state-of-the-art technologies were explored, involving faculty and staff from all around the world, and integrating them into a highly complex socio-technical system, a Global Virtual Lecture Hall that comprised the following features:

- A **weekly "base" lecture** that provided the fundamental concepts of the research field (2009–2012);
- Live **guest lectures** by high-profile speakers from around the world who added to the attractiveness of the series (2009–2012);
- **Videoconferencing** as the main technology to deliver these lectures in an interactive fashion (2009–2012);
- Theoretical and practical **group exercises** that accompanied the lecture series, enabling students to collaborate on assignments (2009–2012);
- A **web-based resource** as sustainable knowledge base and platform to build an international, multidisciplinary community on embodied intelligence (2009–2010, redesigned with more community-supporting features 2011–2012);

- **Recordings** of all lectures to enable students to review the classes and to allow participants from further universities to follow the class and participate in the exercises (2009–2012);

- Three-dimensional **collaborative virtual environments** (3-D CVEs) for international student collaboration on exercises (2009–2010);

- Practical **group projects** [Büc12] to give students the chance to work on actual, real-world problems in robotics and AI (2009–2010);

- Interactive **"Discussion Sessions"** in the virtual environment to complement the video-conferences (2010);

- A powerful **robot simulation software** to enhance some of the group exercises (2011–2012); and

- Hands-on **robot competitions** to foster student/tutor collaboration locally at the participating sites (2012).

The implementation, application, and year-over-year improvements of the technologies used in the ShanghAI Lectures are outlined in sections 3.4 to 3.8; how these features were perceived by the participating faculty and staff is the topic of chapter 4.

Documents that described the contents of the course and listed requirements, target audience, textbook, dates and times, and technical information, were sent to all participating sites every year (see Appendices G, H, and I).

3.3 Pedagogical considerations

Based on the positive feedback obtained from the AI Lectures from Tokyo in 2003 (see 2.8.1), the decision was made to again focus on an interactive lecture style, so that there was always the possibility for members of the audience to ask questions to the lecturer or to contribute to a discussion. To participate in these interactive lectures, students had to physically come to the lecture halls which on the one hand gave the lecture a certain "value" (e.g., it required some effort by the students to participate) and on the other hand contributed to a sense of presence, as the participants were not "isolated" (e.g., at home or at an Internet café) but attending the course together with their peers. Based on this reasoning – but also due to technical and financial considerations –, a live stream of the classes was not offered.

Every week, one or two guest lecturers, usually high-profile researchers from Artificial Intelligence and Robotics, were invited to not only give a broad overview of the field, but also to add more examples and real-world applications of the concepts presented in the "base" class. After each of these presentations, students had the opportunity to discuss with the guest lecturer.

To complement the lectures, group exercises were created that would be solved collaboratively by virtual teams composed of students from different universities. These exercises could be done online from basically anywhere, provided that students had access to the necessary bandwidth and computing power for the 3-D world and the robot simulator software.

In addition to these exercises, students were encouraged to work on one of 12 group projects, real-world problems issued by scientists at the AI Lab as part of their regular research projects [Büc12].

Making available the recorded lectures and guest talks had the advantage that students could review them as many times as they needed. It also enabled those who could not join the videoconference to follow the course asynchronously, and increased the visibility of the lectures in general, as the recordings were accessible from anywhere without registration. However, similar to experiences in the AI Lectures from Tokyo, this contributed to the fact that as the semester progressed, some students (who apparently were not so much interested in actively participating in the lecture) did not come to the lecture hall anymore. In the interest of the students, there was no attendance control – in order to pass the course, the minimum requirement was to achieve half of the exercise points.[50]

To encourage students to come to the lecture hall and pay close attention to the class, the main lecturer announced the *F-O-R Competition* in one of the first weeks each semester: Should he forget to mention the Frame-of-Reference Problem[51] in a lecture, the first student to notice would get a bottle of champagne or, alternatively, a box of chocolates. From time to time the lecturer would deliberately "forget" the F-O-R Problem to give students the chance to actually win the prize.

Unlike in a traditional face-to-face lecture, the main lecturer did not stay at one university during the semester. Instead he visited some of the participating sites and delivered his lecture from there, to interact directly with students and faculty, or even from other "external" institutes in case he had to attend a conference somewhere else during the semester. This increased the number of venues that needed to be set up and tested, but also demonstrated that in the Global Virtual Lecture Hall not only students can participate from anywhere but the lecturers as well. Many of the participating sites appreciated the fact that the lecture was held, at least once, "live" from within their premises.

3.4 Technological foundation

Previous experiences (see Section 2.8) and the support by SWITCH, the Swiss Education and Research Network, led to the decision to use basically the same, proven (but updated) technological foundations as in the AI Lectures from Tokyo, with the addition of a new technology: a virtual world. Initially, the three main components of the ShanghAI Lectures project were therefore:

Videoconference connecting lecture halls in an interactive live "broadcast" that transmitted

[50] However, it was left to each participating university to define their "local" requirements for students to pass the ShanghAI Lectures.

[51] The Frame-of-Reference Problem is a fundamental concept in AI that underscores the importance of discriminating the perspective of the observer and the perspective of the agent to be observed.

audio/video as well as computer screens among the participants; supported by a background communication channel for the technicians and tutors (see 3.4.1, 3.4.2, 3.4.4);

Website for the community of students, staff, and lecturers to provide more information about themselves and to access materials such as exercises, recorded lectures, and articles for further reading (3.4.5, 3.4.5); and

Three-dimensional collaborative virtual environment where the participants logged in as avatars (virtual representations of themselves) to communicate and work together on group assignments (3.4.6).

Given that the ShanghAI Lectures Project was a technological experiment at least as much as an educational and social one, the technologies used are elaborated in greater detail in the following sections with respect to their usage in the ShanghAI Lectures.

3.4.1 Videoconferencing

The first main component of the ShanghAI Lectures was the videoconference. In general, "videoconference" is the umbrella term for a number of different telecommunication technologies that enable two or more participants, usually called "endpoints", to join a common meeting, even though they are physically separated – similar, in principle, to a conference call by telephone with an additional visual channel. In the ShanghAI Lectures, the endpoints were entire lecture halls or seminar rooms at the respective universities ("sites") that were connected to each other via a central hub. In the case of guest lectures, an endpoint often consisted of a small office with only one or two individuals (the speaker and a technician).

While other technologies, namely virtual worlds (see 3.4.6) are opening up new possibilities for interaction, videoconferencing is still best suited to assess the level of interest of the other participants by looking at their body language [Mar05, IJ13] and therefore contribute to a sense of presence similar to a physical meeting.

Protocol

There are several competing videoconferencing standards in use. One of the more popular and widespread ones is H.323, a collection of protocols that define the connection, compression and transmission of audio and video data in packet-based networks. All sites that participated weekly in the ShanghAI Lectures were equipped with H.323 compliant hardware, so-called *codecs*[52], though in a few instances (e.g., one-time guest presenters), software endpoints were used.

A competing videoconferencing technology is *Access Grid*[53], which offers more flexibility in terms of image sources (e.g., several camera images can be displayed at the same time) and collaboration (data sources such as the participants' computers can be integrated). While

[52](en)coder-decoder, i.e., equipment that *encodes* the signals from the attached camera and microphone and transmits them to the other parties and at the same time receives and *decodes* the incoming streams back into audio/video signals for the screen or projector and loudspeaker, according to the specifications of the protocol.

[53]`http://www.accessgrid.org`

there are other advantages Access Grid has over H.323, it is not (yet) widespread among universities, is complex to set up and maintain [Sua07] and therefore was not practical for use in the ShanghAI Lectures.

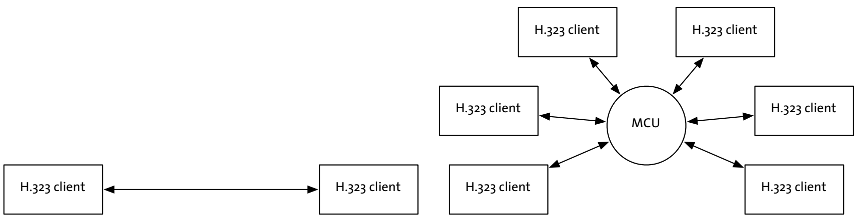
The very popular Skype webcam conference software and similar systems are targeted towards home users and have their own (usually proprietary) set of protocols that are incompatible with the H.323 standard, which made it necessary for some guest speakers to install H.323 compliant software on their computers, which was often difficult because of firewalls, incompatible routers, or other issues, and made extended testing necessary.

In short, there are different standards for different applications which are often mutually incompatible. For the ShanghAI Lectures a "common denominator" had to be defined, which – as described in the first paragraph – turned out to be the H.323 protocol that was already used by most universities.

Connection types

Videoconference connections can be categorized in two types: Point-to-point and multipoint (Figure 3.1). In a point-to-point connection one endpoint connects directly to the other by "dialing" the other's IP address or H.323 identifier, i.e., there are no intermediary nodes.

For multipoint conferences, a star topology is employed: each participating endpoint is connected, in a point-to-point fashion, to the central *Multipoint Connection Unit* (MCU) that mixes and distributes the audio/video signals.



(a) Point-to-point

(b) Multipoint

Figure 3.1: The two basic connection types in H.323 videoconferences.

The MCU also manages the audio levels and the screen layout the endpoints receive, i.e., how the individual video streams (the video from the participating sites) are arranged on the screen. In the ShanghAI Lectures the following screen layouts were used (see Figure 3.2):

- Just before and right after the lecture, all connected sites were visible in a 3×3, 4×4, or 4×5 grid to give an overview of the participants and thus stimulate the sense of being part of a community.
- During the lectures, the main speaker was displayed in a larger frame than the other sites, a selection of which were arranged in the remaining space. This was the stan-

(a) Overview of all sites that are currently connected.

(b) Regular lecture layout with the "main site" in the upper left corner.

(c) Guest lecture layout with enlarged "guest site".

(d) After a guest lecture: Two discussing sites enlarged.

Figure 3.2: The four most used screen layouts in the videoconference.

dard layout used throughout most of the videoconferences, as it gave the "main stage" to the lecturer while still conveying the feeling to the individual sites that they were connected to a network of lecture halls.

- Videos or animations were usually displayed fullscreen (i.e., with no other sites visible) to provide the best quality possible.
- In case of a discussion between two sites, e.g., after a guest presentation, the two parties were placed next to each other, surrounded by smaller frames of the other sites.

Switching between these layouts and controlling the placement of sites in specific positions in the layout were done manually (by the author of this thesis) by selecting the respective options on the MCU in a web interface, which usually took 2–3 seconds until the changes were in effect. It would be possible to automatically place the site with the loudest sound in the "main" frame, but as there were many acoustic glitches (for example, if one site forgot to turn off their microphone), this was not feasible as it would have resulted in a constantly-changing arrangement (visual distraction).

In the videoconference every endpoint had a label that showed up on the screen (see Figure 3.2) as well as in the web interface of the MCU. Usually these labels read "HDX 4244S769" or "Room 15", which may be acceptable for "local" use, i.e., within a university network. For the ShanghAI Lectures all sites were encouraged to rename their endpoints with more general and meaningful labels, e.g., "University of Zurich" or "THINKLab Salford", which made it much easier to operate the MCU, and to address individual sites during discussions.

Bandwidth

Bandwidth determines the quality of the audio and video signals a participant sends and receives. To achieve clear audio and TV-sized "standard definition" (SD) video, 768 kbit/s were necessary. At most sites the network infrastructure was sufficient to allocate this data rate to the videoconference. Only in some special cases, e.g., when guest lecturers participated from home or from another place with low bandwidth, a data rate of 384 kbit/s was allowed, resulting in comparably blurry video and muffled sound. This was not optimal for a lecture, but usually acceptable as it did not happen too often.

In an H.323 multipoint videoconference, the audio and video streams are optimized for the bandwidth available to each endpoint individually. Therefore, sites connecting with a lower bandwidth only receive a reduced video resolution and low-quality audio from the MCU but do not otherwise influence the other, higher-bandwidth sites in any negative way, except of course for the quality of the audio/video they *send*. High-definition (HD) videoconferencing had been introduced some years ago and offers much improved picture and audio quality at higher bandwidths, e.g., up to 2 Mbit/s. While the MCU could in principle accommodate endpoints that connected with HD quality, most of the participating sites had neither the necessary equipment (e.g., HD cameras and projection systems) nor the required bandwidth available. In addition, the recording system (see 3.4.3) was not ready for HD video. Therefore, the ShanghAI Lectures were held in standard definition.

Number of concurrent sites

SWITCH provided their MCU which had a capacity of up to 20 concurrent users. Three of these "slots" were normally reserved for technical purposes such as connection tests, so there was an effective limit of 17 participating sites. This was just right for the ShanghAI Lectures, as generally the same 12–15 "core" universities were connected to the conference every week, complemented by one or two additional participants who connected just once for a guest presentation. In case of additional need, the reserved slots could be released for the ShanghAI Lectures.

While it would have been possible to let more sites join the videoconference by cascading several MCUs or using a more powerful one[54], this option was abandoned as increasing the

[54]for example, the infrastructure of DFN (Deutsches Forschungsnetz, the German equivalent of SWITCH) can host up to 40 participants in one multipoint conference, see https://www.vc.dfn.de/en/video-conferencing/

number of participating sites would have decreased the level of interactivity: The duration of each lecture was limited, and in each lecture as many of the connected sites as possible should be actively involved somehow. With too many sites in the videoconference not all could be considered in the interactive parts, which would have turned the videoconference into a TV-style broadcast for these participants. In addition, experience has shown that having to address more than about a dozen sites is rather confusing for the lecturer [Pfe10a].

Audio

Multipoint videoconferences are susceptible to audio issues that are often ignored in the planning phase. Most importantly, the audio setup of every participating endpoint should be equipped with an echo cancelling system, otherwise all other sites may hear a feedback (echo). This requirement could not always be met by the participating sites due to various reasons, e.g., in the case of one-time participants who connected with a software endpoint and could not use suitable headsets or microphones. To prevent "background noise" during a presentation, all sites were periodically reminded to mute their microphones. While it was possible to mute an endpoint on the MCU via the web interface, this procedure was comparatively slow and error-prone: it was not always obvious which endpoint caused the echo, and the web interface took several seconds to reload. This made it impractical especially during a discussion when several sites took quick turns in talking and the screen layout had to be switched too (which was done on another "page" of the web interface).

Whenever an endpoint connected or disconnected, an acoustic signal was heard in the videoconference and the screen layout updated to accommodate the change in video streams. To minimize this disturbance, all sites were asked to connect well before the actual lecture started. However, fluctuating bandwidth or an otherwise unstable network could cause some sites to disconnect and reconnect at any time during the course of a lecture.

Testing

Apart from individual connection tests with all the sites, three "general rehearsal" videoconferences were organized to offer a realistic setting and to make sure everything would be ready for the first lecture. This proved helpful for those sites that decided to participate, as they could not only get familiar with the other sites but also understand how important it is to have the local technology under control, e.g., to turn off microphones when not talking and to position cameras and lights such that the local moderator or lecturer could be seen well by the other sites.

3.4.2 Screen sharing

Virtually all lecturers used electronic slides during their presentations, e.g., Powerpoint, Keynote, or PDF. These had to be visible at all sites that were connected to the videoconference.

`technical-details/capacities.html`

While the H.239 extension of the H.323 standard provided for parallel transmission of computer screen data over the videoconference connection, not all endpoints supported this feature. For reasons of compatibility and redundancy (videoconference and screen sharing used different servers), a software solution was employed for the ShanghAI Lectures: The *Adobe Connect*[55] server infrastructure, provided by SWITCH, enabled presenters to share their computer screen via a plug-in for the web browser which had the advantage of being simple to setup and transparent to the user: once connected to the system, lecturers could operate their presentation software as usual – whatever was displayed on the presenter's "local" screen was also visible at the other sites. This included, for example, handwritten annotations that were added to the slides using a digitizer (a graphics tablet with a special pen to write on top of the display). The main lecturer frequently used this functionality to include comments from the audience in his presentation; in particular, he prepared empty slides that could then be filled with keywords prompted by students (Figure 3.3, right side).

Figure 3.3: SWITCHcast recording of the videoconference (left) and screen (right) with annotations.

This screen sharing system was suited best for relatively static slides, as it transmitted visual data at a rate of about 1–5 frames per second; however, animations and videos did not display fluently, and there was no sound. The system used for recording the lectures (see below) made it necessary to limit the presentations to relatively static slides anyway; if lecturers wished to play videos, they had to be shown in the videoconference channel.

[55] `www.adobe.com/products/adobeconnect.html` (product page), `http://www.switch.ch/interact/` (Adobe Connect is part of the services provided by SWITCH). This software offers additional functionality, such as text chat, a whiteboard and webcam-based videoconferencing; however, in order to keep the communication streams separate, only the screen sharing function was used for the ShanghAI Lectures.

To this end, an audio/video mixer in the main lecture hall – Shanghai (2009) and Zurich (2010–2012), respectively – was set up that connected a computer to the H.323 endpoint like another camera. All lecturers were asked to provide their movie files to the main site's staff beforehand, so that they could be fed into the videoconference instead of the camera image by playing them on that computer.

3.4.3 Recording

All lectures and guest presentations were recorded and made available on the project website (see 3.4.5) using *SWITCHcast*[56], a collection of tools and practices provided by SWITCH. Originally intended for the recording of normal "local" classroom-based lectures, the SWITCHcast Recorder software combined the audio/video from the cameras and microphones in the lecture hall with the screen image from the lecturer's computer and then uploaded these synchronized data streams to the SWITCHcast server for further editing and publishing. Using a web interface, unwanted scenes (such as delays due to connection issues) could be removed, chapter markers were added, and then the recording was published in three formats: Streaming Flash video, downloadable QuickTime movie (both of which played the lecture video/audio plus the slides at the same time), and iPod-formatted "podcast" movie that only played the slides accompanied by the audio track.

In the main lecture hall, the SWITCHcast Recorder was connected to the H.323 endpoint (for audio and video) and to a separate computer running Adobe Connect (for the slides). Once a lecture was over, the recording was immediately uploaded, edited, and published on the ShanghAI Lectures website (Figure 3.4).

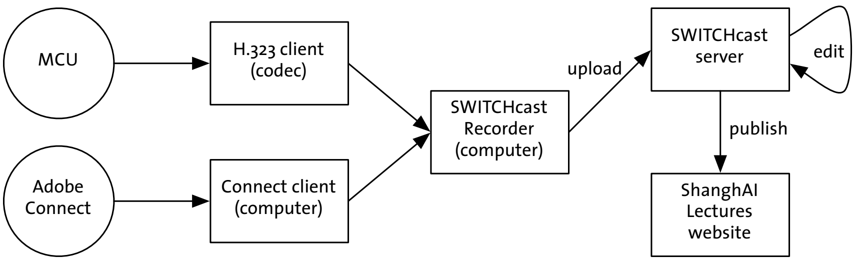


Figure 3.4: Recording schematics.

A number of universities and individual students used these recordings to follow the course asynchronously, for example if their time zone made participation in the live videoconference difficult – or simply because there was no more "space" available on the MCU to accommodate additional sites. Figure 3.3 shows a screenshot of the streaming Flash version with the videoconference channel on the left and the synchronized slides on the right

[56]http://cast.switch.ch

(adjusted to be of equal size; the Flash version allows to change the respective screens interactively).

In contrast to the PLAY system used in the AI Lectures from Tokyo (see 2.8.1), SWITCHcast could only record, not stream the lectures. Adding streaming facilities would have induced additional (costly) hardware, bandwidth and required – to keep the lectures interactive – a feedback channel for the external viewers, including some means to collect the feedback and forward it to the lecturer. In order not to increase the complexity of an already highly elaborate setup, it was decided that making the recorded lectures available shortly after they were held would be sufficient for external, "passive" viewers.

3.4.4 Background communication

In addition to videoconferencing and screen sharing, a third "virtual" communication infrastructure was set up for the ShanghAI Lectures that remained unnoticed by the audience, but was crucial for the staff at all sites: text chat for background communication. This was kept separate from the videoconferencing and screen sharing channels in order not to disturb the lecture.

To make it easier for the various sites, most popular text chat systems like *Google Talk*[57], *MSN/Live Messenger*[58], *Yahoo Messenger*[59], and *AOL Instant Messenger*[60] were supported, i.e., the technicians did not have to sign up for another service but could use the programs they were already familiar with.

These text chat systems require very little bandwidth, can be used free of charge, and are even available on mobile devices – i.e., a computer is not necessary; this was particularly useful when already a lot of hardware had to be installed for the videoconference and screen sharing. Every participating site was required to have at least one staff member online in one of these chat programs during the videoconference, so that it was possible to quickly communicate "in the background" without disturbing the class.

Most of the sites did not have to communicate with each other, but rather stay in touch with the organizing site (Shanghai in 2009, Zurich in 2010–2012), which resulted in a one-to-many style communication topology (not many-to-many) that was rather demanding for the organizer.[61]

3.4.5 Community website

The second main component of the ShanghAI Lectures was the "online resource", a platform for the community of students, researchers, lecturers, and other interested individuals.

[57] `http://www.google.com/talk`

[58] `http://windows.microsoft.com/en-US/messenger/home` – according to Microsoft, MSN will be merged into Skype in 2013 and the Live Messenger will disappear (except for users in China)

[59] `http://messenger.yahoo.com`

[60] `http://www.aim.com`

[61] During the videoconferences, the author of this thesis controlled the MCU, communicated with the other sites, periodically checked the SWITCHcast Recorder, and sometimes also operated other equipment such cameras and the computer used to play videos.

The website `http://shanghailectures.org` was set up to provide access to information related to the lectures, such as slides, exercises and their solutions (for registered students), and further reading materials; also all recorded lectures and guest presentations were made available there. Eventually the website also served the purpose of a course management system.

Students who wanted to participate in the exercises had to sign up on the ShanghAI Lectures website, which included providing some personal and study-related information (such as gender, age, languages, home university, semester, etc. that were then used in the research on virtual team behavior) and accepting the terms and conditions; students could opt out of being part of the research.

Lecture repository

One major purpose of the website was to serve as a repository of the recorded lectures and guest talks. All these recordings were made available publicly (no registration necessary), and more talks were added independently of the ShanghAI Lectures schedule, such as recordings from conferences or seminars that were related to the general topic "Embodied Intelligence". By early 2013 well over 100 videos were available, some of which included extended information such as abstracts, a biography of the speaker, further reading materials, and a PDF document of the slides.

Implementation

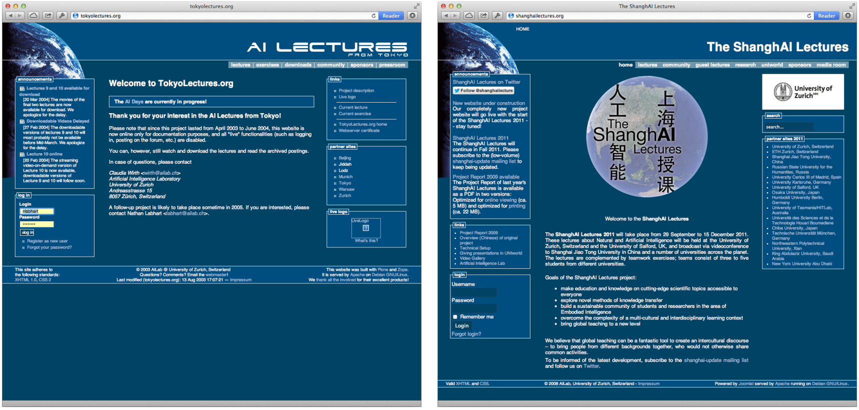
While Facebook was already one of the most popular social networks and had been used for educational projects before [RCZP09], access to it was (and still is) not easily available in some countries, namely China. In addition, there are open questions about the control and ownership of user data (uploaded content as well as log data/usage metrics). For reasons of independence and flexibility, the website for the ShanghAI Lectures was set up from scratch and hosted on servers at the University of Zurich.[62]

The original website, used in 2009 and 2010, was implemented using the open source content management system *Joomla*[63] at version 1.5, the same framework that was powering the website of the AI Lab at that time and was therefore already known to the organizers.

A number of extensions to the Joomla core functionality were added to integrate discussion forums, user registration, profile pages, and a video gallery. The design of the website was based on the look and feel of the AI Lectures from Tokyo site (Figure 3.5).

[62] Nevertheless, some project team members decided that a Facebook page would be a good way to generate more visibility for the ShanghAI Lectures and set up such a page. However, as personnel resources were low and the project website required more attention, the Facebook page did not get many updates and was essentially abandoned.

[63] `http://www.joomla.org`



(a) The AI Lectures from Tokyo website…

(b) …and the original ShanghAI Lectures website (2009–2010).

Figure 3.5: Comparison of the original ShanghAI Lectures website with the AI Lectures from Tokyo site.

Initially, some of the built-in communication features of Joomla, such as messaging, were disabled with the intent to steer the students towards the collaborative virtual environment instead (which was important for the research on virtual team behavior, see below). However, most students simply resorted to other communication channels, e.g., Skype, e-mail, MSN, and other instant messaging platforms [Lon10].

Because initially the ShanghAI Lectures were planned as a one-time event, managing the students and their exercise points was done manually using spreadsheets, and no need for course management facilities was identified. This changed after two years, when the website was reimplemented (see Section 3.7.3): The original set of functional requirements and the interface design were found to only partially match the actual usage patterns during the lecture series, and it became necessary to change some features and the overall structure of the website.

3.4.6 Collaborative Virtual Environment

The third integral component of the ShanghAI Lectures, at least in the first two years, was the three-dimensional collaborative virtual environment, a virtual world that was established as a platform for the students to work together on exercises and as a discussion facility [HGL+09] (see Appendix A). It seemed that the time was right for the usage of 3-D CVEs, as a prediction by the Gartner Group stated that "80 percent of active Internet users (and Fortune 500 enterprises)" [Gar07] would have a presence in a virtual world[64]. Letting stu-

[64] That press release also contained some caveats: financial investments into virtual worlds should be limited as it would take some time for useful and successful virtual world frameworks to emerge from the very active scene.

dents gain experiences with virtual world technologies would therefore help prepare them for their professional careers. To conduct research on virtual team behavior, a custom implementation of an open-source 3-D CVE was set up.

Technology

After evaluating the then-available open source 3-D CVEs (commercial systems did not offer the flexibility to add e.g. a logging mechanism, and many of them were not accessible in some countries), *Open Wonderland* (OWL) was selected as the platform for the ShanghAI Lectures. At that time, OWL was still called *Project Wonderland* and actively supported by Sun Microsystems, who had a record of contributing to education with their open source projects.[65] Sun originally developed Wonderland as a "virtual office" for collaboration, so this framework provided many tools aimed at team meetings and collaboration like a PDF viewer, whiteboard, and sticky notes, that were not available in the competing frameworks. In addition, basically any X11 based application (such as a word processor or a web browser) that was installed on the OWL server could be used inside the virtual environment. The users (avatars) could therefore collaborate on documents and look up information on the Internet without having to leave the 3-D CVE.

Provided that the users wore stereo headsets, they had an immersive audio experience: an avatar's voice came from the direction of where it was located, relative to one's own position, just as in the real world, and the volume decreased as one moved away.

Wonderland was written entirely in the Java programming language, which promised platform independence and a large pool of programmers who could potentially adapt and extend OWL to answer custom needs. There was already a growing community of users and developers who published modules (extensions of functionality) that were aimed at educational projects on the OWL website. The developments made for the ShanghAI Lectures were also contributed back to the community eventually.

Release version 0.4 of OWL was tested in the context of "feedback sessions" in a seminar with about 30 students in spring 2009. The two seminar leaders were streamed into the virtual world using an IP webcam, students logged in as avatars and presented their seminar work in the form of a PDF document within OWL. This worked quite well; however, shortly after this test version 0.5 of OWL was released to the public with the claim that it would be the basis for future developments (offering more speed, nicer-looking graphics, a resizable window, modular extendability, and other improvements), so the decision was made to use this new version for the ShanghAI Lectures. However, by the time the lectures started, not all features and functionalities from version 0.4 had been ported to version 0.5, e.g., there were neither webcam viewer nor a stable video player (an experimental video player was made available to the ShanghAI Lectures by one of the core OWL developers).

[65] After Oracle Corporation had bought Sun in early 2010 and halted development on Project Wonderland, it was renamed to Open Wonderland and released to the open source community.

UNIworld

Using the OWL framework a virtual environment called *UNIworld* was developed, which was intended as a place for the student teams to work collaboratively on the exercises that accompanied the lecture series. The custom architecture of UNIworld with meeting rooms for the student groups, presentation stages, and common spaces was implemented by a 3-D artist/programmer from Saint Paul College in Minnesota, USA, based on designs created by HENN StudioB in Berlin[66] and an Experience Designer from the University of Lugano [Smi10, Sch10]. The virtual environment, in its original design, comprised five team rooms that were connected to each other via the central area where every avatar appeared upon login to the virtual world, and a common stage for presentations (Figure 3.6).

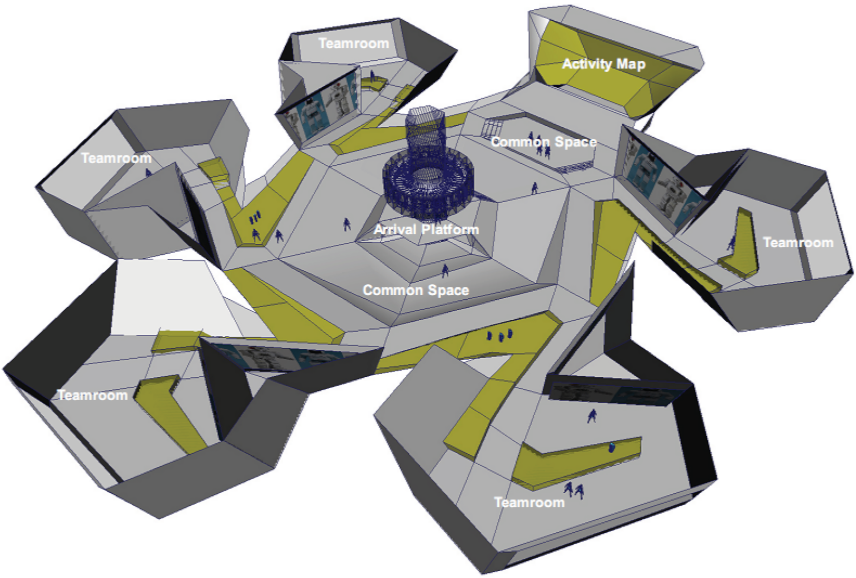


Figure 3.6: The original architectural design of UNIworld in 2009, called "The Paw": An arrival platform, connected to five team rooms and a common presentation stage. Design by HENN StudioB and Andreas Schmeil [Sch10].

As one of the extensions to the original OWL framework, the program code of UNIworld included a *Data Acquisition* system that made it possible to track avatar behavior in the virtual world, i.e., to record the movements and actions of an avatar. In combination with the architecture that was carefully designed to study interactions within and between groups and a *Visualization Tool* that showed the recorded movements and actions of avatars graphi-

[66] `http://studio-b.org`

cally, projected on the floor plan of the virtual world [Has10], this facility could be used for quantitative research on the dynamics of social networks in general; in particular, the data was collected for research on virtual team behavior [RH10, Has11].

Several weeks before the lecture started, load tests showed that one OWL server could handle about 20 concurrent avatars. As by that time several hundred students were expected to participate, a way had to be found to balance the load. Again in collaboration with Saint Paul College, a total of 20 independent Wonderland servers were set up (8 in Minnesota, 12 in Zurich) [Kun10]. Student groups were then assigned to one of these 20 servers.

Technical improvements to the OWL framework led to a new design of UNIworld in the following year, as only one server was necessary (see 3.6.3).

3.4.7 Exercises

To complement the lecture series, exercises were offered to those students who wanted (or had) to get credits for the course. Inspired by paper-based exercises from a former face-to-face version of the lecture but updated for an online distribution and submission, these exercises were meant to deepen the understanding of the topics presented in the lecture and to give small examples of practical research in robotics and AI.

With the exception of a short multiple-choice quiz that was issued to the students in the second week, so that they could assess by themselves how much they already knew about basic concepts of (embodied) AI, the exercises were designed to be solved in groups consisting of students from different universities. This had two reasons: First, one goal of the ShanghAI Lectures project was to foster collaboration among the students on an international level; and second, such group work would generate data for the research on virtual team behavior.

To create groups that were composed of "interesting" constellations, a *Team Builder* program was developed that took into account various properties of the students (such as age, sex, country – information that was collected during the registration process). This program also included a *Faultline Calculator* in order to quantify the "convergence among several dimensions of diversity within a group" [Has10].

During the planning phase of the ShanghAI Lectures, a number of group exercises were designed to exploit the possibilities of a 3-D CVE [Sch10]; however, it turned out that implementing them in the then-current version of OWL was much more complex than anticipated, and due to a lack of personnel resources only some of these exercises could be implemented as intended (in 2009 and 2010).

3.5 ShanghAI Lectures 2009: Establishing the basics

The first series of ShanghAI Lectures took place from 15 October to 17 December 2009 with 12 sites that joined the videoconference lectures on a weekly basis (see Appendix E). Emphasizing the "edutainment" character of the course, an artist at the AI Lab in Zurich created a title sequence that listed all participating sites, lecturers, institutions, companies, and sponsors in an entertaining way. This movie of about one and a half minutes was then played in the beginning of every videoconference to mark the beginning of the lecture, and again at the end to conclude the videoconference.

To underscore the importance of this project for Shanghai Jiao Tong University, the vice president of SJTU delivered a welcome note to the global audience in the beginning of the first lecture. This was then followed by a round of introductions of the connected sites, so that everyone had a better idea of the community.

In the second lecture, the president of the University of Zurich addressed the global audience with his welcome note (delivered, ironically, from the lecture hall at ETH Zurich). The first student presentation was held in this lecture, too.

The remaining 8 sessions saw more student presentations, three guest lectures from the US (where it was very early morning for the speakers) and one from Australia (where it was late evening); one guest talk was even held by a robot – that presentation was preprogrammed, there was no interaction or discussion with the audience.

3.5.1 Videoconference

As mentioned in Section 3.1, Shanghai Jiao Tong University was the "main site", i.e., the base lecture was given (mostly) from there. One auditorium was set up with the necessary hardware (codec, camera, wireless microphones and base station, audio and video mixer, projectors, monitors, loudspeakers, lights, etc.) every Thursday for the class (Figure 3.7). After the videoconference, all equipment had to be removed again as the lecture room was also used for other classes. There was no videoconference-ready lecture hall available on the campus, only small meeting rooms which could not accommodate the local audience.

Most of the supporting infrastructure (MCU, screen sharing server, recording facilities, etc.) were located and operated in Zurich. To ensure a stable connection between China and Switzerland, technicians at SJTU applied for a prioritized connection at CERNET[67], which provided the Internet backbone between China and DANTE/GÉANT[68] in Europe.

The "second main site" was the University of Zurich, where the ShanghAI Lectures originated. However, the one lecture hall that would have been perfectly suited for the videoconference (as it was equipped with a high quality codec, a recording system, several screens, and microphones on every table) was already reserved for another class on Thursdays and could therefore not be used. Because the main lecturer of the ShanghAI Lectures was also accredited at ETH Zurich, a suitable lecture hall could be used there. Thus, students from the University of Zurich came to the classroom at ETH Zurich and joined their peers there (instead of "only" in the videoconference).

3.5.2 Screen sharing

During the round of introductions, some sites did not share their screens but uploaded their slides into Adobe Connect, which resulted in delays and, in some cases, distorted the format-

[67] The China Education and Research Network, the Chinese equivalent to SWITCH; `http://www.edu.cn/HomePage/english/cernet/index.shtml`

[68] The European research and education network; `http://geant3.archive.geant.net/pages/home.aspx/`

Figure 3.7: Lecture hall at Shanghai Jiao Tong University, China. The cable on the floor leads to a socket in a nearby office – there were no Internet facilities available in the lecture room.

ting because of fonts that were missing within Adobe Connect.

Even though all guest speakers were informed of the limitations of the screen sharing system (see 3.4.2) and asked to test their set-up of Adobe Connect beforehand, not all speakers followed that advice. This resulted in some "wasted time" at the beginning of the respective guest lectures, as the speakers had to install the screen sharing software first. In a few cases, the lecturers did not provide their videos beforehand; the recording of these guest talks can be used to demonstrate the low frame rate of the "slides channel".

3.5.3 Recording

Due to human error, the recording system was not started on time, therefore the first few minutes of the very first lecture were lost. In the remaining lectures, the person in charge of the recording was reminded by text chat a few minutes before the class started. Newer versions of the SWITCHcast Recorder can be set to start and stop recording according to predefined calendar entries; however, especially in the case of guest lectures which sometimes took considerably longer than planned, manual operation of the SWITCHcast system provided better control over the recordings.

3.5.4 Exercises in UNIworld

The original idea was to design exercises for the 3-D CVE using the *Avatar-Based Collaboration Framework* which "puts the collaborating groups into the center of the design and emphasizes the use of distinct features of 3D virtual worlds for use in collaborative learning environments" [SE10]. For example, exercise ideas ranged from color-coding parts of robot models as actuators/sensors, cheap/expensive, etc. to sitting inside a robot, "perceiving" the world only through the robots' sensors and acting on that sensory input, and then discussing the behavior of the robot with the other group members who had been observing from the outside, without knowing how the robot "perceived" its environment [Sch10].

Technical restrictions of OWL, as well as limited personnel resources, caused these innovative collaboration patterns to be moved up to the 2010 lecture series; in 2009 students used the OWL tools (experimental video player, shared applications) to work on assignments that were still closer to "traditional" paper-based exercises.

For collaborative learning in UNIworld to run smoothly it would have been necessary that each participating university provided their students with access to OWL from a local computer lab, as well as technical support. While all sites were informed of the technical requirements, many did not or could not offer sufficient infrastructure to their students, which led to a somewhat unsatisfactory experience with the exercises.

3.5.5 Conclusions[69]

While several members of the core team in Zurich who organized the ShanghAI Lectures 2009 had previously worked on similar projects (see 2.8.1, 2.8.2), for most universities an interactive videoconference-based lecture series with such international participation was a completely new experience. The ShanghAI Lectures were well received in general, as many universities were able to participate in a lecture series they would not be able to offer otherwise, and students could broaden their horizons both on an academic as well as personal level by interacting with scholars from around the globe. Participants came from six continents: Asia, Africa, North and South America, Europe, and Australia.

The overall concept – a base lecture series, guest talks, and collaborative exercises – was successfully established. Some issues with the 3-D CVE were to be expected, given that it was an experimental setup regarding technology, educational concepts, and also as a research platform. However, towards the end of the project it became clear that major improvements would be necessary to make the 3-D CVE not only usable, but also useful and used[70].

[69] A more detailed "Final Report" that also contains financial considerations and an evaluation of student responses, is available online at `http://shanghailectures.org/project-report-2009`.

[70] A popular view in Human-Computer Interface research is that there are "three 'use' words that must all be true for a product to be successful; it must be: useful – accomplish what is required […]; usable – do it easily and naturally, without danger of error, etc.; used – make people want to use it, be attractive, engaging, fun, etc." [DFAB04]

3.6 ShanghAI Lectures 2010: Focus on interactivity

Building upon the experiences collected in 2009, the second series of ShanghAI Lectures was organized around the same main components: The base lecture held via videoconference, complemented by guest talks, collaborative exercises among students from different universities, and the community website. However, to further explore educational uses for the 3-D CVE, the number of videoconference sessions were reduced to 7, and 5 interactive meetings were held in UNIworld instead. The course lasted from 30 September to 16 December 2010. The title sequence was cut down to the first 20 seconds, as most of the information displayed in the remaining minute of the movie did not reflect the new program and change of participating sites.

The first lecture started off with general remarks about the course and a short look back at the 2009 series. The remainder of that session was filled with a round of introductions so that the sites got to know each other. As this took longer than anticipated, a few sites had their self-introduction in the second lecture.

Only two sites from 2009 did not join in 2010, but five new universities took part in the weekly classes. A new line-up of carefully chosen guest speakers complemented the basic lecture with examples from current research in Artificial Intelligence, Robotics, and related fields (see Appendix E). As an experiment with the 3-D environment, two of these guest lectures were held within UNIworld as part of the Discussion Sessions.

3.6.1 Videoconference

This time, the University of Zurich was the "main site". As the lecture hall that would have been perfectly suited (see 3.5.1) was still unavailable, another room was booked that had professional audio/video equipment already built in; the rest of the necessary hardware (codec, recording station, video mixer) was then installed in the back of the lecture hall by the author of this thesis together with an audio/video technician of the University of Zurich. This auditorium, conveniently located near the AI Lab where the ShanghAI Lectures were organized, became the standard lecture hall in Zurich for the remaining years.

As SJTU was not the main site anymore, there was no need for all the special "broadcasting equipment" from 2009, and a normal lecture hall was set up with just the basic videoconferencing devices, like all other sites.

At one of the newly participating universities, the national telecommunications provider for as of yet unknown reasons delayed openening the necessary ports for the videoconference; in the first few lectures that site participated via a VPN tunnel over a mobile 3G connection (with reduced audio and video quality, but at least they could participate live).

In the last videoconference there was no base lecture scheduled to be able to use the entire videoconference sessions for five guest lectures. As usual, these presentations took longer than originally planned; with five lectures this resulted in a lot of overtime. The last presentation was delayed further because the guest lecturer had issues getting the screen sharing up and running. This would not have been a problem since those sites that had to leave on time could watch the recording of that last guest presentation later; however, the videoconference session on the MCU was booked until 12:30 CET in Zurich (the lecture was scheduled to end around 12:00, half an hour of "buffer time" was added by default) – and in the middle of the last guest lecture, the MCU automatically announced that the conference was over and stopped all connections. Via the background communication (text chat) a new conference could be set up quickly in close collaboration with a technician at SWITCH, and announced to the other sites so that they could reconnect. In addition to this, the screen sharing channel was temporarily "appropriated"[71] to display an "emergency message" (see Figure 3.8). In the recording the pauses caused by these interruptions were removed.

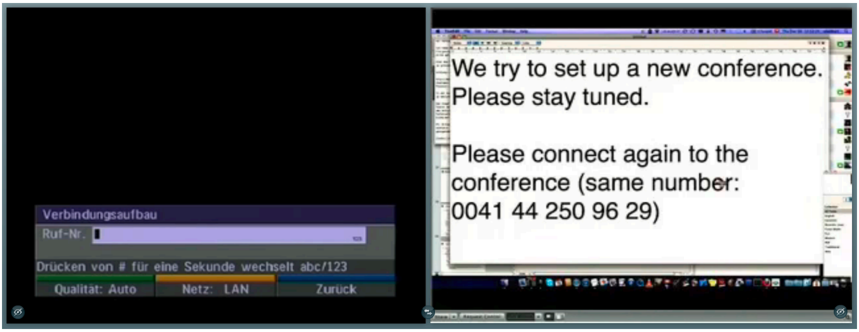


Figure 3.8: Appropriation: Using the screen sharing channel to make an emergency announcement to all sites (screen shot from the SWITCHcast recording of Lecture 7, 2010).

3.6.2 Website

Based on the experiences from 2009, the website was adapted only slightly. For example, it turned out that the Video Gallery feature (where students could upload short movie clips) was hardly ever used; it seems that most students did not "want to use an additional platform, and would rather use existing platforms, such as Youtube" [Lon10]. Therefore the Video Gallery was disabled when updating the website with the new course information.

3.6.3 Exercises in UNIworld

The development of OWL had made some progress since 2009, especially regarding the number of concurrent avatars per server. On the client side, 3-D objects that were "out of sight", i.e., occluded (e.g., if the avatar was facing a wall) or exceeding a certain distance threshold from a user's avatar, would not be loaded for that particular user, which decreased memory and computation requirements dramatically. Therefore, the "landscape" and architecture of

[71] In this context, *appropriation* is the act of using a tool in a way that was not originally intended.

UNIworld were redesigned such that all teams had their own workspace (room) while still being part of the same environment (Figure 3.9). Now only one server could handle the load, though one identical copy of UNIworld was running on a second server both as a backup system in case the first server had issues, and for hosting the Discussion Sessions.

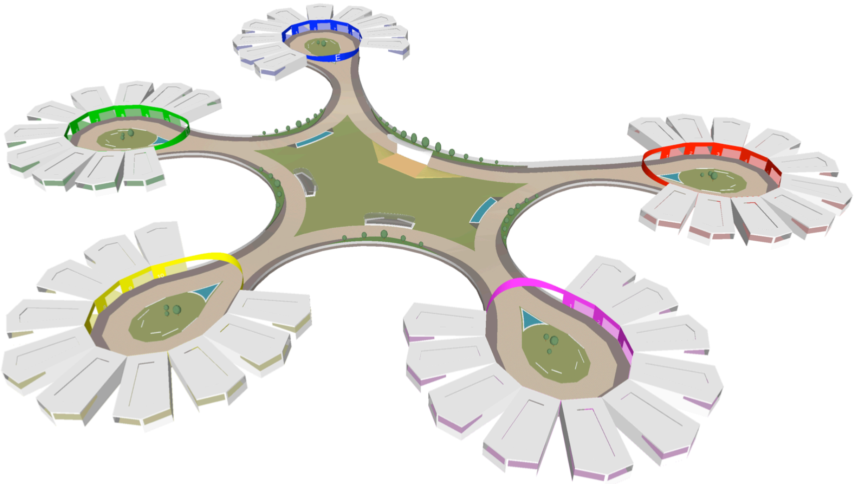


Figure 3.9: The new architectural design of UNIworld in 2010: Five areas with ten team rooms each, connected to a common area that includes two presentation areas, two “ponds”, and a stage.

The exercises were updated to incorporate some of the collaboration patterns that were originally planned for 2009, and a tutorial for UNIworld was published that helped students familiarize themselves with the Wonderland interface and tools, as it turned out in 2009 that using the software was not intuitive for most students.

Before starting with the actual exercises, students had to “decorate” their team room with 3-D objects and pictures to create a more personal environment for the duration of the course. For two optional bonus exercises a separate 3-D CVE using the OpenSim framework was set up [Sch12].

3.6.4 Discussion Sessions

As already mentioned, improvements in OWL made it possible to set up experimental “Discussion Sessions” that complemented the regular videoconference classes. These sessions were planned as interactive meetings in UNIworld where the lecturers and students could take advantage of the collaboration and presentation tools (PDF viewer, video player, sticky notes, pointer, etc.) and discuss topics in an interactive way, (almost) face-to-face, while participating from (potentially) anywhere, i.e., not having to come to the lecture hall as in the videoconference. Students were encouraged to submit questions or suggestions to the lecturer by e-mail prior to the Discussion Session.[72]

Soon it became clear that there would be little input from the students, so the Discussion Sessions turned into more or less regular classes held in UNIworld. There was an increase of interactivity though, probably because students could "hide" behind their avatar (by giving it a fantasy name). The chat window was used throughout the session, and in some cases empty sticky notes were provided to the students to anonymously write down their comments, e.g., when comparing the human brain and a computer (Figure 3.10, left side). In another situation, a guest lecturer in UNIworld prepared two statements and students could "vote" by moving their avatars left or right, next to the respective statement (Figure 3.10, right side).

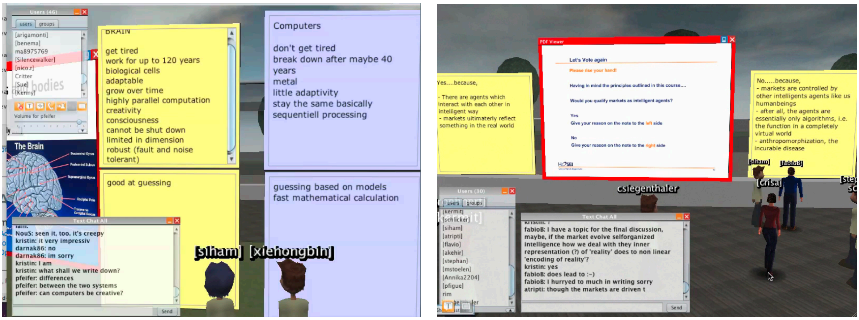


Figure 3.10: Interactivity in UNIworld: Students typing keywords on "Sticky Notes" (left) and "voting" by moving their avatars to the left or right side, depending on their opinion (right).

For the first Discussion Session the lecturer was connecting from Munich where he had to attend a meeting. Due to time constraints it was not possible to test the network setup beforehand, and a firewall setting blocked some of the ports OWL needed for the audio connection – so in the first virtual session, the main speaker was mute and could only communicate via text chat. While this was a disappointing start, it confirms the view that writing is the "basic medium of online expression" [Fee99].

The remaining Discussion Sessions did not suffer from this issue, though it was found that OWL was still too unstable for productive use and alternative 3-D CVEs did not offer the features wanted by the organizers.[73]

[72]This pedagogical concept is similar to the so-called "Flipped Classroom" [Mar12, CS13] where students watch recorded lectures beforehand and come to the classroom to "discuss the topic and begin face-to-face work with the lecturer" [Nor13].

[73]One possible reason for the technical issues is that development of the 3-D framework was slowed down and became less coordinated as it transitioned from the Sun-supported "Project Wonderland" to the open-source, community-supported

Attendance in the Discussion Sessions decreased over time – in the second session there were between 40 and 50 avatars present[74], this number dropped to around 30 in the fourth Discussion Session and around 20 in the last one. This was taken as a further sign that students were not willing to spend too much effort with UNIworld if they did not feel an advantage over the videoconference class; as mentioned above, they were not much different from a regular class and did not take sufficient advantage of the possibilities of the 3-D CVE.

3.6.5 Recording

Recording the videoconference lectures with the SWITCHcast system worked without any major issues. To record the Discussion Sessions, two computers were set up, each with a screen and audio capture software running in parallel to the UNIworld client. One avatar was the "cameraman", which was placed in a fixed position, slightly above the ground, to record the session from a bird's eye perspective. The other avatar was actively controlled by the author of this thesis to mingle with the students, and thus provided an active, more "embedded" perspective. Once the Discussion Session was over, the two resulting videos were combined, alternating between the two perspectives, to create a more interesting recording, and uploaded to the SWITCHcast system for publication on the website just like the videoconference recordings.

3.6.6 Conclusions

The concept of a videoconference-based lecture series continued to be the defining feature of the ShanghAI Lectures. While the Discussion Sessions showed that interactivity could indeed be fostered by the 3-D CVE, it became also clear that UNIworld, despite the improvements already introduced to the underlying OWL framework and the stronger embedding into the educational concept, was still not mature enough to become as valuable to the project as the videoconference and the website. The ambitious plans for UNIworld did thus not come to fruition, and it was decided to put the use of 3-D CVEs on hold for the foreseeable future and concentrate on the community aspects of the website instead.

3.7 ShanghAI Lectures 2011: Focus on web community

The suspension of UNIworld meant that there would be no 3-D CVE for the students to interact, and no Discussion Sessions either. To make up for this loss of interaction facilities, the website was to become the main platform for collaboration and communication and was therefore reimplemented from ground up. The base lecture and guest presentations (see Appendix E) were held exclusively in the videoconference again, like in 2009. This lecture series took place from 29 September to 15 December 2011.

"Open Wonderland".

[74] the "record" number were 61 avatars in this session

3.7.1 Videoconference

The University of Salford had been participating in the ShanghAI Lectures since the beginning. To celebrate the opening of MediaCityUK, a new production campus of the British Broadcasting Corporation (BBC) in Salford with which the University of Salford collaborates, Salford was chosen to be the "main lecture site" for this semester, with Zurich the "second main site" hosting the MCU and recording infrastructure, similar to the situation with Shanghai Jiao Tong University in 2009.

Perhaps to make up for the loss of issues with 3-D CVEs, 2011 turned out to be the year with the most videoconferencing issues.

It began, ironically, with the discovery that MediaCityUK did not have any videoconferencing facilities that were compatible with the H.323 protocol used in the ShanghAI Lectures, so one room at MediaCityUK had to be equipped with an "improvised" videoconferencing setup that was then used a few times before switching back to the premises of the University of Salford where proper equipment was available.

In Zurich, the video output of the codec in the lecture hall occasionally exhibited small visual glitches, such as pixellated images or false colors. While not a serious problem, it had a negative effect on the quality of the recordings. A new codec was therefore deemed necessary, and as the audio/video services of the University of Zurich at first did not have a replacement codec ready, a company specialized in videoconferencing equipment agreed, on short notice, to support the ShanghAI Lectures by lending one of their codecs in return for being mentioned as a sponsor.

When installing the state-of-the-art device in the lecture hall, however, it became apparent that the built-in audio and video infrastructure was too old to support digital connections. This made additional cable adapters and active converters necessary, which in turn increased the complexity of the setup. After the first lecture it became clear that the new codec was not really suited for the old lecture hall; fortunately the audio/video services of the University of Zurich were finally able to provide one of their own codecs which then worked rather reliably during the remaining classes.

In the second week the lecturer was in the US and gave his class from the University of Vermont in the early morning (due to the time difference). As there was no other possibility to annotate his slides (see 3.4.2), the lecturer had to use a Windows "Tablet PC" which turned out to be very slow, taking several seconds just to skip to the next slide. Since then the lecturer always carried a lightweight graphics tablet when traveling to be able to annotate the slides using his own computer.

During one of the guest presentations in lecture 3 the videos that were played at the main site and fed into the videoconference suddenly could not be seen anymore. An investigation into this issue revealed that at one of the sites, someone accidentally turned on the H.239 mode for transmitting computer screen data over the videoconference "channel" (see 3.4.2), which caused the MCU to change the layout of the incoming video streams. This had the effect that the video signal from Zurich (which included the played movies) was hidden. The affected guest lecturer did not let this issue distract her, and she continued with her presentation – just without the videos. This example shows how "fragile" the videoconferencing technology still is, especially in such a complex setup with over a dozen different endpoints – and how important it is that lecturers are able to cope with such issues.

The other videoconferences went without major technical issues. Lecture 4 began a few minutes later than planned because of a very different reason: The lecturer was in Japan but accidentally had his watch set to the Chinese time zone, which meant that it was running one hour behind. Fortunately, a test connection with the Japanese site was scheduled one hour prior to the actual lecture, so instead of running extended tests the lecturer had to immediately begin with the class.

3.7.2 Social media

As mentioned in 3.4.5, a Facebook page had been set up in 2009 to advertise the ShanghAI Lectures; however, nobody took proper care of that page and it was eventually abandoned – after all, China was an important part of the project, and Facebook was not accessible there. Twitter was unavailable in China as well, but to add at least some "Web 2.0" flavor to the ShanghAI Lectures project, the Twitter account @shanghailecture was set up as an additional channel for the dissemination of information such as new additions to the lecture repository, i.e., only information that was also accessible on the ShanghAI Lectures website anyway.

3.7.3 Website

To compensate for the loss of interaction facilities that resulted from suspending the 3-D CVE after two years, and to automate the management of students and groups, the website was completely overhauled in 2011: After evaluating potentially useful Course Management Systems (Moodle, OLAT), drawing some inspiration from Facebook regarding "social" features (such as direct messages, friendships, and group pages), and conducting usability tests, the ShanghAI Lectures website was reimplemented using the *Drupal*[75] framework as part of a Master Project at the AI Lab [CHZ12]. In addition to custom-developed extensions to Drupal, third party services were included, for example the live chat system *Envolve*[76]. To reflect the major functional changes, the visual appearance of the website was also completely redesigned (Figure 3.11).

Migrating content from the old website to the new one was a matter of days, as most of the information (including old user profiles) could be moved semi-automatically. The repository of guest lectures required more manual work, but in the end the extra effort resulted in a more consistent and accessible website.

The whole process of managing the students, their assignments, and exercise points could then be administered online. Students were able to discuss group exercises with their peers and contact their respective tutors easily on dedicated "Study Group" pages (Figure 3.11, right side) that provided facilities for uploading files (e.g., preliminary solutions), submitting

[75] `http://drupal.org`

[76] `https://www.envolve.com` – in exchange for being mentioned on the website as a sponsor, the company provided a free licence of their chat system.

the final version to the assigned tutor, and for changing the group in case the collaboration was not successful.

Tutors received the submissions online and, after checking them against the example solutions provided by the teaching assistants in Zurich, entered the grades. The website kept track of each student's exercise points even if they changed the group.

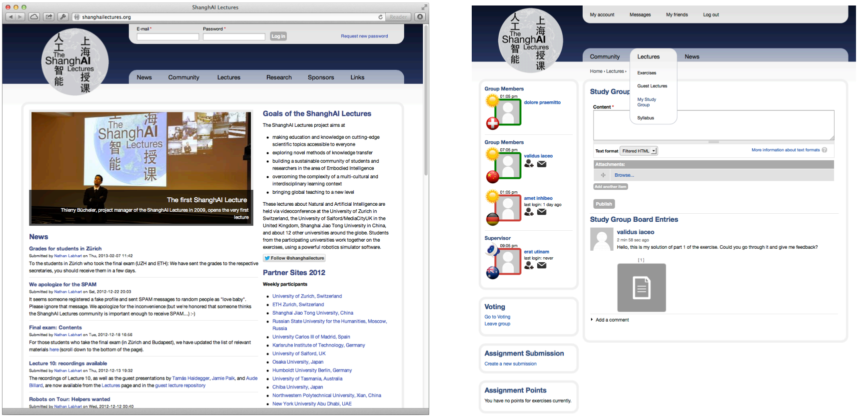


Figure 3.11: The redesigned ShanghAI Lectures website and a mock-up of a "Study Group" page.

3.7.4 Exercises

Collaborating with Cyberbotics Ltd., developer of a professional-grade robot simulator, the ShanghAI Lectures could provide all registered students with a free licence of *Webots*[77] for the duration of the entire semester. The exercises were therefore rewritten to take advantage of this software, letting students experiment with different robot models.

3.7.5 Conclusions

The new website offered rich communication and collaboration functionalities to the community members and simplified the management of students, exercises, and grades substantially. Providing the Webots robot simulator software to all students allowed the exercises to be more comprehensive in terms of robotics and experimentation.

Issues in the videoconference indicated the need for more technical and social protocols, which resulted in an improved documentation of the technologies and their suggested use (Appendix I) as well as a document tailored specifically to guest presenters (Appendix J).

[77] `http://www.cyberbotics.com/overview`

3.8 ShanghAI Lectures 2012: Consolidation and refinement

The last series of ShanghAI Lectures was using the same technical foundation as the 2011 edition, updated with two additional (voluntary) group exercises/competitions that involved physical robots. A number of new guest speakers contributed to the broad appeal of the course (see Appendix E). This series started on 27 September and ended on 13 December 2012.

3.8.1 Videoconference

Although in Zurich the same lecture room was booked as in the last two years, the office in charge of the room reservations was not aware of the fact that this specific auditorium was needed because of the installed infrastructure. After noticing that the number of students that were estimated to take this course at the University of Zurich was low in comparison to the number of available seats in that lecture room, that room (which had already been set up with videoconferencing equipment during the summer break) was assigned to another course with more students – without noticing the ShanghAI Lectures organizers, who found this out one week before the first lecture, when coming to the lecture hall for the "general rehearsal" with all the other sites. Immediately after notifying the other participants that the lecture hall in Zurich could not be used (and therefore the rehearsal had to be canceled), two parallel emergency processes were started:

On the one hand, the office managing the rooms at the University of Zurich was contacted regarding this issue; and on the other, in case the "proper" lecture hall could not be used, an "improvised" videoconference setup was installed, by the author of this thesis, in a seminar room at the AI Lab.

Fortunately the "proper" lecture hall could be reallocated to the ShanghAI Lectures just in time for the first lecture. This incident shows that if one relies on external room management, it is important to make sure they understand why a specific lecture hall is necessary, and to ask for confirmations for any room reservations.

In one of the first guest lectures of this semester, a real-time translation system from English to Spanish was demonstrated. Originally it was planned to continue using this system for the rest of the semester, at least for the base lecture, but organizational and technical issues made this impossible: The system would have had to be trained to the main lecturer's voice and vocabulary first; in addition it required a sophisticated setup (microphones and other equipment) that would have to be transported, installed, and calibrated wherever the lecturer went (as usual, the base lecture was given from different sites).

3.8.2 Lectures

This year the round of introductions in the first lecture was left out, as most faculty and staff already knew each other from 2011 and students could watch the recordings from that year to get an overview of the participating sites. Only when the main lecturer visited one of the sites to give his class from there, the local representative would give a "site presentation" at the beginning of the respective class.

3.8.3 Recording

Several weeks prior to the first lecture, a new version of SWITCHcast Recorder had been released that allowed for a higher frame rate and better overall quality of the slides, as well as a higher resolution of the video stream. However, this would have required a more powerful computer to be installed in the lecture hall. The University of Zurich's IT infrastructure department had not scheduled such a replacement in time for the beginning of the semester; therefore, the exact same infrastructure was used for the recording as in previous years.

3.8.4 Website

Apart from fixing bugs that became apparent when resetting the course management system for the new semester, such as the inadvertent publication of example solutions, the website could be mostly reused from 2011 regarding functionality and design. The most visible change was the addition of a live Twitter feed to the page to show messages that contained the hashtag #SHAIL or were sent from the @shanghailecture account.

3.8.5 Exercises and competitions

Also the exercises were mostly identical with those from 2011, as the Webots package was again provided to the students for simulation experiments. In addition to these exercises two "hands-on" robot competitions were introduced to finally give students the chance to work on real, physical robots. A few weeks before the lectures started *Aldebaran Robotics*[78] approached the ShanghAI Lectures organizers to promote their NAO robot in education, and at the same time, the *EmbedIT* toolkit that had been developed by one of the assistants in Zurich [Ass13] was ready to be deployed. Two assistants in Zurich took care of the robot competitions.

For the **EmbedIT** competition one kit (consisting of one servo board, one master board, one Bluetooth module, and miscellaneous cables) was sent to every participating site along with a "shopping list" for other necessary parts (batteries, servo motors, glue sticks, cable binders, insulation tape) and a description of the task. Each university then formed a local team that used the EmbedIT kit to explore different morphologies – the goal was to come up with a design that moved over a distance of 1.2 meters as fast as possible. At the end of the semester, each team submitted a video of their robot to the assistant in charge who then determined the winner during the last lecture.

In the **NAO** competition, the original plan was that not every university needed to have their own NAO robot, as those participants that *did* have robots available would provide them to the other sites in a "virtual pool" of robots. Students could send their control programs to a tutor at one of the NAO-equipped universities who then uploaded it to their robot(s) and

[78] `http://www.aldebaran-robotics.com/en`

recorded the performance. However, in the end there were not enough physical NAO robots available and the complexity of managing all the students and robots became too complex. Therefore, the competition was eventually done mainly in simulation (using Webots as well as the simulation software package that comes with the NAO robot). As with the EmbedIT competition, the assistant in charge selected the winning team which then presented their solution in the last lecture.

3.8.6 Conclusions

The last year of ShanghAI Lectures saw only minor modifications to the overall concept established in 2011, e.g., first steps to incorporating more "Social media" features by integrating the Twitter feed on the website (and actively managing this Twitter account), or the demonstration of a live translation system. The biggest change was the introduction of physical, hands-on robot competitions. Especially the EmbedIT kit perfectly exemplified the ideas presented in the lecture series.

3.9 Outcome

In the context of the ShanghAI Lectures 2009–2012 a number of technologies and educational concepts were explored as potential components of a Global Virtual Lecture Hall. On the technical side: interactive multipoint videoconferencing, screen sharing and chat facilities, content and course management systems, lecture repositories, three-dimensional collaborative virtual environments, robot simulator software, social networks, live translation systems, and very different types of physical robots (a highly sophisticated but relatively rigid commercial robot, and a very simple but extremely flexible robotic toolkit); on the educational/social side: weekly interactive base lectures, guest presentations, various community-supporting features such as group exercises, interactive meetings in a virtual world, group projects based on real-world problems, and hands-on competitions.

3.9.1 Numbers

In those four years of ShanghAI Lectures, about 170 people – faculty, staff, other helpers – were involved, including almost 60 high-profile speakers who contributed guest presentations. Teaching assistants created more than twenty unique exercises to complement the base lecture, and roughly 1000 students around the world signed up for the course.[79]

The recordings of all four years' worth of lectures and guest presentations were accessed almost 30'000 times by mid-2013 (see Table 3.1).

[79] the number of individuals who only followed the class without registering on the ShanghAI Lectures website it not available.

	SHAIL 2009	SHAIL 2010	SHAIL 2011	SHAIL 2012	total/year
2009	4881				4881
2010	4286	2777			7063
2011	2799	3081	1474		7354
2012	798	816	1576	2177	5367
2013	577	573	749	1625	3524
total/course	13341	7247	3799	3802	28189

Table 3.1: SWITCHcast access numbers of all recorded base lectures and guest presentations from 2009 to 2012, streaming and downloadable versions combined (as of 2013-06-03).[80]

3.9.2 Personal assessment and limitations

The author of this thesis has been part of the ShanghAI Lectures project since the beginning and was present in every lecture, coordinating the videoconference and communicating with speakers, technicians, and assistants at all sites. This proved extremely helpful for collecting observational data and providing insight into almost all aspects of the project.

Even though the ShanghAI Lectures were originally planned as a one-time series only, many of the concepts turned out to be sustainable over the following years, such as the videoconference-based main lecture with guest presentations, the collaborative exercises, and the community website with a lecture repository.

After deciding to continue with the series, the basic idea of Action research could be applied by identifying weaknesses and then implementing remedies in the following year; in addition, novel components (such as the "Discussion Sessions" or the robot simulator) could be explored for their suitability in a Global Virtual Lecture Hall. Due to financial and time constraints some of the planned improvements could only be partially implemented, even though it was possible to win the support of some companies (mostly software licences, know-how, and other "in kind" contributions).

All in all, students seem to have liked the videoconference lectures and guest presentations, and the lecturers were enthusiastic about giving talks in the Global Virtual Lecture Hall, as it was a novel experience even for experienced speakers to being able to address such a diverse and globally distributed audience.

The 3-D CVE should probably have been made an optional component rather than being forced on the students, especially since UNIworld was not working as intended. In addition, the research track on virtual team behavior was too prominent: "most importantly, the students signed up for a lecture, not for a research project" [Has10]. Leaving away UNIworld in the last two years was not an in-principle decision against 3-D CVEs, as some levels of interactivity could indeed be achieved (see 3.6.4); once the underlying frameworks have matured (and the necessary computing power is available to all students), 3-D CVEs could become an integral part of the Global Virtual Lecture Hall (see 5 below).

With the end of the ShanghAI Lectures, most of the lectures and guest presentations are about to be published on the *Robohub* blog[81] to increase visibility in online communities, even as the ShanghAI Lectures website will be kept online for the foreseeable future, including the lecture repository hosted on SWITCHcast.

[81] `http://robohub.org` describes itself as "an online platform that brings together leading communicators in robotics research, start-ups, business, and education from around the world."

4 Evaluation and results

In this chapter, the ShanghAI Lectures project is reviewed from the point of view of faculty and staff, based on information harvested from the interviews and surveys, and from personal observations and experiences by the author of this thesis. This insight into how faculty and staff perceived the ShanghAI Lectures then leads to the identification of success factors that positively contributed to the ShanghAI Lectures and also points out the potential challenges that need to be taken into account when implementing a Global Virtual Lecture Hall.

4.1 Data collection

Even though more than 170 individuals were involved in the ShanghAI Lectures as faculty and staff, not all were tapped for data collection. For example, the majority of guest lecturers participated only once in the four years of lectures (see Appendix E) and therefore were not considered, as there was no continuity compared to e.g. weekly or yearly participants. An invitation to fill in an online survey (or optionally schedule an interview) was sent to all 85 assistants and technical staff at the various sites; 19 chose the survey and 8 agreed to be interviewed. Many of the regular lecturers had busy schedules and were not available during the data collection period: only 10 could be interviewed, one preferred to fill in the questionnaire. In short, there were 38 respondents, 11 lecturers/site responsible persons and 27 assistants/technical staff. The respondents are listed in Appendix F; in the following sections the interview and survey data are anonymized. The original data is available from the author upon request.

The 18 interviews were done in a semi-structured way, i.e., a set of initial questions – similar to those in the questionnaire – were posed that led to an open-ended conversation. Semi-structured interviews offer "flexibility to approach different respondents differently while still covering the same areas of data collection" [Noo08]. All interviews were recorded, and hand-written or typed notes were taken. With the exception of one interview where the professor and one of his assistants were present,[82] only single-person interviews were conducted. Of the 18 interviews, nine were done in Skype (six using only audio) and nine live (face to face).

After closing the online questionnaire and concluding the interview transcription period, a mixed-method analysis was used to extract relevant data from the collected responses. On the one hand, predefined labels such as *positive/negative* and *technical/social/institutional/personal/other* were attached to the responses; on the other hand, coding approaches from Grounded

[82] The assistant helped to translate but did not otherwise add to the content of the interview.

theory were used to extract a number of factors, for example, *collaboration, community, guest lectures, language, overall concept, time zones, UNIworld, videoconference, website*.

In the following paragraphs, respondents are labeled as [[GL*n*]] = Guest Lecturer; [[SR*n*]] = Site Representative (usually a faculty member); [[TA*n*]] = (Teaching) Assistant; [[TS*n*]] = Tech Staff. Phrases in *italics* are actual quotes from respondents.

4.2 Overall concept

One of the biggest advantages of the ShanghAI Lectures was that a course could be offered at many universities where it would not be available otherwise [[SR3, SR6, TA3, TA23]]. Through innovative application of technologies [[TA9, TA11]], perspectives on Artificial Intelligence that were new for many participants [[SR2, TA8, TA19]] could be taught at many sites at the same time, potentially alleviating the restrictions imposed by physical lecture halls [[SR2]]. By using such new technologies, participating lecturers had the chance to distinguish themselves from their more traditional colleagues [[GL1]]. The *"open availability"* [[TA4]] of the lecture recordings immediately after each class, allowing students to register and collaborate in the group exercises even if their home university did not participate in the regular videoconference [[TA21]] – contributed to the *"coolness factor"* [[TA8, TA20]] of the project. Some found this lecture series *"effective"* to broaden academic view and were *"absolutely fascinated"* by it [[TA22]].

While the overall concept was received very well – *"general idea and execution is very good"* [[SR11]], also from the perspective of the intended audience: *"students are content"* [[SR8]] –, there were concerns that the whole series depended on the main lecturer and that participating universities had little control over the content [[TA10]].

Personal observations

The success of the initial ShanghAI Lectures concept in 2009 caused us to continue with this lecture series. We tried to keep the basic components – a main lecture, complemented by guest presentations and collaborative exercises – intact while at the same time exploring new methods and sometimes also abandoning features that did not work well. These efforts were recognized in the sense that new sites joined the project by word of mouth and the "ShanghAI Lectures model" even became part of an EU project proposal [NMTP+12].

The main reason why some universities left the project was a lack of resources, which usually meant no available teaching assistants.

4.3 Organization and technology

Deploying the ShanghAI Lectures would not have been possible without a lot of organization and time-consuming efforts from faculty and staff [[SR2, SR5, TA10]] at the main site as well as locally at each participating institute.

A natural restriction for sites at the "outer ends" of the covered area are different time zones [[SR3, SR4, TS1]]. In the case of the ShanghAI Lectures this may have led to *"less* *communication"* [[TA14]] as the classes took place early in the morning or late in the afternoon/evening, when *"many of the students preferred to do something else"* [[SR5]]. Even though there were a few guest lectures from the U.S., the *"lack of American professors"* was apparent [[TA13]]. While some thought the time zone issue was *"solved quite nicely"* by including European and Asian sites [[SR2]], others suggested to only include European universities [[TA17]] to facilitate participation.

Overlapping semester dates [[TA10]] and differing regulations at the individual sites made it difficult for some universities to include the ShanghAI Lectures in their regular curriculum. The wide array of educational levels of the participating students [[TA11]] and their different requirements were sometimes seen as an impediment to collaboration [[SR6]]. For example, not all students had to take a final exam [[TA12]] and thus did not need the exercise points, which led to *"different levels of engagement"* in the group exercises [[TA12]]. To improve this situation, it was suggested to not mix students with different requirements [[TA5]]. Awarding more credit points might make participation more attractive, too [[SR5]].

Getting the *"state of the art"* [[TA12]] technology working was facilitated by the *"really good"* tech support that resolved questions quickly [[TA20]]. At many sites the videoconferencing hardware was already available; for some, though, purchasing the necessary equipment was seen as a rather costly investment [[TA4, TA17]]. Especially for Chinese sites, where access to the educational networks is expensive [[SR3]], ensuring the required bandwidth was a cost factor [[SR2, TA11]]. The expenses were *"worthwhile"* though [[SR12]]. At some public universities, the application procedure for a "special internet line" took a long time [[SR7]], so the technical requirements needed to be announced early. Apart from that, advertising the class was done in a satisfactory way [[TA4]].

Using more or less standardized technologies [[TA4]] could not prevent issues that interrupted the lectures [[SR8, TA7, TA21]]; fortunately, they were not perceived as *"too present during the lectures"* [[TA20]]. From the lecturers' points of view, the lecture hall setup had a large influence on how they could deliver their class; for example, some could not see the videoconference screen while presenting [[SR3]], others were restricted in their movements due to the camera position [[SR9]]. In general though, the technology was found to be *"amazing"* [[SR1]]. It was suggested to not change anything and *"just go with it"* as dealing with occasional hiccups is *"part of the game"* [[SR12]]. The fact that the main lecturer visited some of the other sites personally, despite all the distance teaching technology, was much appreciated [[TA10]].

Personal observations

The ShanghAI Lectures succeeded thanks to the extraordinary support from teaching assistants, tutors, technical staff, and other helpers at the involved universities and companies. The assistants in Zurich closely collaborated with the author of this thesis during the videoconference by operating some of the equipment (microphones, cameras, video mixer). The support and expertise by technicians of the University of Zurich and SWITCH proved invaluable, as did the generally very friendly communication among all involved tech staff and tutors.

The technical and social complexity of such a project cannot be overstated. While standards like H.323 were introduced to alleviate some problems, videoconferencing is still subject to many issues that stem from the interplay from technology and its users: Lecturers and staff need to be aware of the constraints imposed by the technology, e.g., turning off microphones to avoid feedback, or waiting a few seconds before talking (because the screen layout needs to be switched). It remains to be seen whether videoconferencing technology will be adapted such that inexperienced users can handle it, or whether there will always be the need for skilled technicians to be present during the lectures.

The biggest issue, though, was not technical but of organizational nature: Regarding the credits students could get for attending the course, our approach was to offer the regulations of the University of Zurich to the other sites and let them decide how much they wanted to adapt, as every university had their own "local" rules. This had an effect on the collaborative exercises, as some group members did not (have to) work as much as others.

From a financial perspective, we tried to keep everything as low cost as possible. There was considerable financial support for the initial lecture series in 2009 [Büc10], but for the remaining three series no big investments were available on behalf of the main site, except for in-kind contributions such as the working time of the assistants who were paid by their respective research projects, the infrastructure which was provided by the University of Zurich, and some equipment, services, and software licences that were provided by sponsors[83]. The course was provided for free to the participating sites; however, they had to take care of local investments (such as videoconferencing equipment and salaries for tutors and tech staff) by themselves.

4.4 Lectures via videoconference

The main feature of the ShanghAI Lectures, the AI course held via interactive videoconference, was one of the most popular items mentioned by the respondents.

The teaching style was perceived to be different and *"not so academic"* [[TA19]] compared to other classes, especially at Russian and Asian sites [[SR5, TA6, TA12]]. Some found that the teaching style did not take into account the possibilities and restrictions of the technology enough – *"conventional classroom feedback does not apply"* in a videoconference where switching between sites takes time [[TA22]]. Regarding the content, which was also different from other classes [[TA6]], some praised the textbook as being *"well written"* and containing *"useful references"* [[TA19]] and appreciated the wide array of topics that were presented [[SR11]] – but at the same time find fault with a lack of details [[TA10]]. Despite being called *"superficial"* by some [[TA3, TA5]], however, the lecture was *"really interesting"* [[TA20]] and seen as motivating the students to share ideas, discuss topics, and work together [[TA1]].

Compared to more passive, *"dead"* [[TA18, TA22]] video-based courses, such as the offerings from Coursera or Udacity [[TA17]], the ShanghAI Lectures provided a *"unique"* [[TA19]], *"fascinating"* [[TA13]] experience by being interactive, i.e., involving the audience.

[83] `http://shanghailectures.org/sponsors`

The inclusion of videos and live demonstrations in the videoconference was deemed adequate for the topic, as a *"hardcore math"* class, in contrast, would not benefit from such a multimedia setting [[TA5]].

The project was recognized to be pioneering the use of telecommunication technologies in higher education [[TA6]]. There seems to be a real chance for universities to "overcome" the threat by MOOCs, as some respondents pointed out that without the possibility of feedback and interaction with the lecturers, *"we do not need the university"* [[SR2]]. At certain sites the ShanghAI Lectures were taken as an example to encourage colleagues to use interactive videoconferencing more often [[SR9]].

The technical setup (keeping the video of the speakers and their slides separate) felt *"more like a real class"* [[TA17]]. While it was *"nice to see the other sites on screen during the lecture"* [[TA7]], interactivity could be improved if it was possible to better recognize the participants, e.g., see their faces [[SR11]].

Some suggested to organize a *"warm-up session where participants get to know each other"* [[SR3]]. One guest lecturer pointed out that based on his experience, interactivity in a virtual meeting can be further stimulated if the participants meet in real life first and get to know each other personally [[GL1]]. Perhaps a different technical implementation would stimulate more interaction [[SR11]].

Providing the questions in advance to those sites that would later be called on could help students to prepare [[SR5]] and saved time; on the other hand, some felt there was too much *"planned interactivity"*[[TA3]] and more "active" participants could lead to more interruptions of the lecture [[TA17]]. The observation that *"not only Chinese students are shy but also e.g. students in Zurich do not want to answer questions"* [[SR2]] contrasts with the popular opinion that this is a *"culturally specific"* phenomenon [[SR10]].

Personal observations

The "casual" teaching style employed in the main lecture, and the topic that appealed to a broad audience, provided the ideal content for the ShanghAI Lectures setup. This also means that this kind of a Global Virtual Lecture Hall is probably not suited for any arbitrary class – there should be a match of topic, lecturer, and technology (see the "Educational balance" principle in Appendix K); different contents require different levels of interactivity.

4.5 Guest lectures and recordings

The invited talks were much appreciated by the respondents, some of which gave guest lectures themselves – an *"interesting experience"*, with an audience much wider than at a conference [[SR12]]. Apart from the fact that these videoconference-based guest lectures eliminated the need for travel [[GL1, TA16]] and thus contributed to an environmentally-friendly education [[TA5]], they provided a broad view [[SR2]] of the research field that went beyond the content of the course textbook [[TA3]].

For students who *"otherwise just read 10-year old textbooks"* [[SR2]] and research papers [[SR5]] it was attractive to listen to famous researchers *"only five meters away"* [[SR1]]; also the teaching assistants (many of which were doctoral students) enjoyed the convenience of hearing high-quality talks, comparable to MIT offerings [[TA16]], about the latest developments in robotics and to know what is going on in other research labs [[SR9]].

Making the recorded talks available was seen useful in case of absence, e.g., due to illness [[TA9]], as one was able to access the content from home [[TA15]] and *"great for students to revisit materials after the lecture"* [[TA20]]. Online repositories of the lectures have the potential to change the role of the professor from pure "information source" to "coach" – students can access the the content from anywhere and then come to the classroom to discuss questions [[GL1]]; however, making available the recorded lectures without stimulating the discussion during class may lead to students not coming to the lecture hall anymore [[TA9]]. Guest lecturers in general enjoyed the interactive discussion sessions after their presentation [[SR12]]. Recording quality was also mentioned as important: *"some video recordings were of low quality, which distracted from the content"* [[TA4]].

Potential issues arose when in certain guest lectures the topics and overall quality *"do not meet expectations"* [[SR8]]. Some guest presentations were perceived as *"boring, time consuming"* [[TA17]] and as taking time away from the main lecture [[TA3]], especially as the audience could not choose the topic (in contrast to MOOCs) [[TA16]]. As a remedy it was suggested to make available materials about the topic beforehand, so that the audience knows in advance what to expect [[TA3]]. A positive side effect of this would be that students were able to prepare topics for discussion with the guest speakers [[SR1]]. Vice versa it was suggested to inform the (one-time) invited speakers about the participating sites [[SR3]] so that the guest lectures could be tailored to the audience.

Personal observations

Giving a guest presentation in a videoconference is relatively straightforward, or so it seemed. There were still (mainly technical) constraints to take into account during preparation and presentation: For example, slides must not contain any videos; one should look into the camera when addressing the audience; and microphones must not be switched on except when presenting. Regarding the contents, they should be adapted to match the audience's level of expertise – which, in the ShanghAI Lectures, was quite challenging as there were undergraduate as well as doctoral students from various disciplines present. On a positive side, the variety of topics – from rather abstract philosophical ideas to very concrete examples – ensured that every guest lecture was interesting to at least part of the audience.

4.6 Website

In general, the website left a positive impression on the staff [[TA16]] who used it as a *"forum of exchange"* [[TA20]], to discuss various topics [[TA17]], and to *"share ideas with the others"* and *"give feedback"* [[TA22]]. The new version that offered more interaction and communication features was described as *"cool"* [[TA3]]. Its potential was not fully exploited though, as in the perception of one tutor, it was only used for answering questions [[TA10]].

Personal observations

Using a generic, open source content management system like Joomla or Drupal for the course website offered a lot of flexibility regarding the design and functionality. On the other hand, implementing course management facilities such as the ability to assign students to groups or to handle the submission and grading of exercises required a lot of work and was prone to errors. Especially if there are not many resources available for conceptualizing, implementing, and thoroughly testing the website, it might make more sense to adapt a standard course management system like OLAT or Moodle.

The service used for hosting the lecture repository, SWITCHcast, worked very well. In contrast to video hosting sites like Youtube that are difficult to access in some countries, SWITCHcast seemed to be available anywhere without restrictions.

4.7 UNIworld, exercises, and competition

Meant to support the understanding of topics presented in the course, the exercises were designed to foster collaboration among students from different universities. The original idea to use a three-dimensional environment for *"playful exercises"* [[TA10]] was regarded as good and *"modern"* by some [[TA10]] since there is a *"trend"* to move from working in 2-D to 3-D [[SR9]]. However, concerning the actual implementation of UNIworld, responses were less enthusiastic. The user interface was *"overwhelming"* for the users [[GL1]], which only increased the chance for issues such as forgetting to turn off one's microphone [[TA18]]. In addition, a *"mismatch of affordances of a 3-D world and the actual use"* was observed [[SR7]], and it was felt that the 3-D world was *"not really connected to the content"* [[SR2]] of the ShanghAI Lectures and *"forced"* on the students [[TA22]]. Technical issues with UNIworld, such as errors, crashes, and a general slowness [[SR7, TA10, TA20]] distracted even more from the content. It was also more difficult to get immediate feedback from avatars, as it was not possible to see the person's face or gestures [[SR11]] in contrast to the videoconference.

The exercises using the Webots simulator, which was praised as *"professional platform"* [[TA22]], were recognized to be much closer to the content of the lectures than those in UNIworld [[SR10, TA10]], which was *"not worth the effort to set up"* as the *"yield was too small"* [[SR5]]. Some suggested to keep UNIworld and make it an optional component, because it was still seen as an *"interesting, good idea"* [[SR11]]. One issue with the exercises that cannot easily be solved is the fact that some students have other time consuming classes and assignments [[SR2]] which prevents them from investing too much effort in the ShanghAI Lectures exercises. Still, the exercises were seen as a good *"quantitative index of success"* of the students [[TA21]].

As part of the student competition, physical collaboration using robots [[TA17]] was regarded as *"very useful"* [[TA19]] and a *"really great idea"* [[TA20]]. Such a competition where students can show their results to each other could well be the goal of the lecture series [[SR9]], as it proved to be very motivating for most students [[SR1]]. For some, however, the lack of a grading curbed their enthusiasm to participate [[SR11]].

Personal observations

The teaching assistants in Zurich created all the exercises, example solutions, and guidelines for grading, often on short notice as topics changed or technical issues required some of the intended tasks to be adapted. Defining all contents early and then sticking to the plan would have helped a lot. We included selected guest lectures in the list of materials students had to prepare for the final exam, in 2012 some guest lecturers were even invited to provide their own questions. It might be interesting to incorporate materials from the guest presentations also in exercises.

Grading the exercises depended on the tutors at the participating sites who took care of the student groups assigned to them, answering questions and sometimes forwarding them to the main organizers. With very few exceptions, the nature of the exercises required a human to check – unlike multiple-choice quizzes that can be automated, evaluating short "reports" and checking data and graphs from simulation experiments requires a certain expert understanding of the subject.

A more thorough evaluation of 3-D CVEs and the available resources to adapt them to the needs of the ShanghAI Lectures would probably have resulted in a more realistic approach – our enthusiasm was not shared by the students who were forced to use a tool that often did not work (even though the course description clearly stated that the software would be experimental).

While UNIworld had great potential to be used for the investigation of social dynamics in virtual communities, it was not obvious to students how this research was related to the topic of the course. Most wanted to learn something about embodied AI; having to spend considerable time and effort as subjects of a psychological study instead was not so much appreciated. Perhaps making the participation in UNIworld optional for those who really want to explore the possibilities of 3-D CVEs, or using UNIworld in a course on social psychology would be met with more goodwill by the students. The use of commercial, more advanced 3-D CVEs instead of an open source framework might be only a partial solution, as the log data is usually not accessible and some commercial platforms are not popular or even available in certain countries.

The NAO and EmbedIT competitions in 2012 required a lot of preparation by the tutors who took care of the respective robots, but the efforts were well worth it, especially in the case of the EmbedIT toolkit that made perfect sense in a class about embodied AI: Exploring morphologies hands-on is as important as studying theoretical concepts. Similar to the projects students could work on in 2009, providing real-world examples and applications of the course topics is very attractive. On the other hand, the NAO robot, while very sophisticated and powerful, was perhaps not the best choice. The focus of the ShanghAI Lectures was not on programming but rather on concepts such as the importance of material properties and the interaction with the environment; the fact that not many sites had a physical NAO available and had to resort to the simulator defeated the purpose of the "hands-on" competition.

4.8 International collaboration and community

The ShanghAI Lectures project was seen as a good model for an *"exchange beyond local research communities"* [[SR7]], as it enabled students to learn how to work with other sites [[SR1]], for example, in the exercises – something that is not possible in MOOCs [[SR11, TA12]]; teamwork is an important aspect of education [[SR9]].

Despite the fact that cultural differences of the participants were considered *"interesting"* [[TA5, TA8, TA14]], not everything went smoothly, as different languages were reported to hinder some study group members from successfully collaborating [[TA20, TA22]]. Apart from that, the ShanghAI Lectures were seen as a good opportunity to train one's English skills, and *"to realize that for most people English is not the first language"* [[SR5]]. By making available some reading materials related to guest lectures in advance, students could get an idea of the content before listening to the presentation and then just *"guess if they don't understand something"* [[SR2]]. Some sites circumvented the "language barrier" altogether by selecting the students who were admitted to the class based on their language skills, e.g., overseas students [[SR1]].

For some of the participating universities the ShanghAI Lectures were an opportunity to strengthen existing connections [[SR9]] and at the same time getting to know new research labs. Some respondents felt that a community in embodied cognition was actually established [[TA18]], even *"that from the start, it's all based around the community"* [[SR12]], and that this community was *"well organized thanks to invididual efforts"* [[SR10]]. The ShanghAI Lectures enabled not only international student exchange [[SR5, TA8]] but at one institute even attracted students to join the research group [[TA9, TA10]].

Personal observations

Collaboration within the ShanghAI Lectures was an extremely interesting experience. As coordinator of the videoconferencing technology since the beginning of the project and overall project manager during the last three years, the author of this thesis had the chance to interact with people from very different cultures and with contrasting "work styles".

Communication about organizational matters took place mostly via e-mail and text chat; videoconferencing was only used for connection tests. In the first year, the project team (consisting of the project manager and the coordinators of the sub-streams – finances, research, experience design, etc.) held some meetings in the 3-D CVE to experience this technology by themselves. Interestingly it turned out that face to face was still the preferred mode for these meetings.

4.9 The Global Virtual Lecture Hall from a community perspective

The ShanghAI Lectures were a technical experiment in global teaching as much as a social one – after all, "building a sustainable community of students and researchers in the area of Embodied Intelligence" was one of the goals of the project. This section presents an excursion into theories from social psychology that can be applied to the community of faculty and staff (and briefly also the community of students) to complement the focus on organization and technology that is predominant in this thesis.

4.9.1 Community aspects in the survey

The initial design of the online questionnaire contained the complete set of questions from the "Sense of Community Index II" (SCI-2, see the next section for an overview of "Sense of Community") [CLA08]. However, in test runs of the questionnaire, many of the original SCI-2 items were found to be "confusing" or "not applicable".[84] In order to keep the questionnaire reasonably concise – after all, "community" was just one of many aspects to be investigated –, only nine items were kept in the final version of the questionnaire. This and the fact that there were only 20 respondents led to a qualitative rather than quantitative analysis of the collected data.

As part of the research concerned with virtual teamwork [HBP09, Has10, RH10], questionnaires were issued to students in 2009 and 2010 that contained some items related to community aspects; with the introduction of the new website in 2011, another study on "social awareness" was initiated, but as of June 2013 the results have not yet been published.

4.9.2 Community of faculty and staff

Concepts from *community psychology*[85] may aid in explaining how faculty and staff of geographically separate sites collaboratively enabled the Global Virtual Lecture Hall. One of these concepts, *Sense of Community* (SOC), sometimes also called *Psychological Sense of Community* (PSOC), is concerned with how and why members of a community – in this context defined as a group of people that are connected in some way – experience this connectedness.

The term SOC had been used to describe both the *outcome* of community membership and the *definition* of what makes a group of people a community. The approach by McMillan and Chavis has become one of the most influential theories of SOC: "Sense of community is a feeling that members have of belonging, a feeling that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to be together" [MC86].

Initially the focus was on communities in the sense of neighborhoods, i.e., physically colocated members, but soon after the field of community theory had been established, a distinction was made between *territorial/geographical* and *relational* notions of community [Gus75], where the latter is "concerned with 'quality of character of human relationship, without reference to location' " (cited from [MC86]).

Both understandings of community apply to the ShanghAI Lectures: While some community members were working together at the same site, e.g., lecturers and their local technical staff, the sites themselves were separated geographically yet formed a community by working together towards a common goal, i.e., enabling the Global Virtual Lecture Hall.

[84] For example, *"I can recognize most of the members of this community"* (item 8 on the SCI-2 questionnaire) does not apply to most lecturers, as they did not usually interact directly with teaching assistants from other universities.

[85] A branch of social psychology that was ignited by Seymour B. Sarason's book *The psychological sense of community* in 1974 [OW04].

Traditionally, SOC had been applied to physical or "offline" communities where the members do not use electronic media for communication. With the rise of Internet-based communities that enabled novel forms and aspects of communication (e.g., media-rich environments, or anonymity by means of nicknames and "fake" profiles), a new instrument became necessary as it was unclear whether the traditional SOC measures would apply to the new "virtual" communities [AZM12]. Therefore, an adaptation of the original SOC has been proposed and used in a number of studies [For04, BM04, Bla07]. This *Sense of Virtual Community* (SOVC) can be defined as "…members' feelings of membership, identity, belonging, and attachment to a group that interacts primarily through electronic communication" [Bla07].

Coming back to the definition of SOC, McMillan and Chavis postulate four key elements contributing to the sense of belonging to a community [MC86, McM96]: Membership, Influence, Integration and fulfillment of needs, and Shared emotional connection. These four features are briefly illustrated here (based on [AZM12]) and examples are given of how they apply to the ShanghAI Lectures community.

Membership includes knowledge about who is a member of the community, identification with other members, and a common system of symbols (e.g., jargon). **Examples:** Many of the participating lecturers and assistants were members of the large, partly overlapping scientific communities of robotics and of artificial intelligence and therefore knew each other already; technical staff shared a common symbol set in the form of their knowledge of the audio/video/communication technologies; researchers used jargon such as "emergence" or "kinematic model" [[TA1, TA11, TS2]].

Influence has two aspects: the members' perceived impact on the rest of the community, and the level of influence the community exerts on individual members. **Examples:** Via the guest lectures, researchers may influence other scientists by giving them new ideas; on the other hand, the ShanghAI Lectures as a socio-technical environment influenced the topics of the guest talks, e.g., there was a "general agreement" on the importance of embodiment[86] [[SR6, SR8, TA1, TA11, TA18]].

Integration and fulfillment of needs states that members need to feel some kind of "reward" or "benefit" for being part of a community, which also depends on their status within the community. **Examples:** Giving a guest presentation can increase the visibility of a researcher; staff members usually were paid to work on the project; some tutors received credit points for assisting [[TA12, TA20, TA22, TS1]].

Shared emotional connection means that members share a common history of "events" within the community; the longer one is member of a community and the more interactions happen, the more likely close relationships (and thus a stronger bond) can emerge. **Examples:** Many sites participated several times with the same staff; some guest lecturers contributed talks in two or three series of ShanghAI Lectures [[SR6, TA1, TA4, TA14, TA15]].

[86]Guest talks that dealt with "traditional" AI were received rather critically.

4.9.3 Community of students

As mentioned in the introduction of this thesis, the focus lies not on the students but rather on the faculty and staff. In the context of this section, however, it makes sense to look at the communities that were formed by students, namely, *(Virtual) Communities of Practice* (V-CoP): “Communities of practice are groups of people who wish to learn something by collaborating with other members of the group both in real and virtual world” [Ata12]. One purpose of the collaborative exercises in UNIworld was to support the creation of virtual communities of practice. Success factors for such V-CoPs include Usability, Membership, Sense of belonging, Shared understanding, Sense of purpose, and Time and communication [FGL07], which are listed here in the context of the ShanghAI Lectures in 2009 and 2010:

Usability of the technology: OWL was very demanding in terms of bandwidth and processing power; not all students had easy access to those. The developmental character of the 3-D CVE diminished its usability considerably.

Membership (group members with prior knowledge of each other): Given the fact that groups consisted of students from different universities and with different backgrounds, it was highly unlikely for the group members to know each other prior to the ShanghAI Lectures.

Sense of belonging and paying attention to cross-cultural dimensions: For the purpose of research on virtual team behavior, students with different cultural backgrounds were grouped together, to investigate the effects of cultural diversity [Has10, Has11].

Shared understanding (common routines and work styles): It was up to the students to find a common work style and organize themselves; only some of the tools were provided (UNIworld, website).

Sense of purpose that is achievable via the mediating technology: At least those students who had to get exercise points to pass the course saw the purpose of the *exercises*, even though the purpose of the *technical means* was not clear, as most tasks could be solved without a 3-D CVE.

Time and communication The collaborative exercises usually lasted for only 10 days after which students had the chance to leave their group if they felt they could not work with their peers. Some groups stayed the same during the entire semester, so it can be assumed that the respective members could communicate well.

4.9.4 Discussion

Creating a community is not easy, and there is no “recipe” for cultivating a CoP [SS04]. Especially when students from different universities, each with their own local regulations, are supposed to work together in order to achieve points (which may not be valid at their home university), finding e.g. a common sense of purpose is challenging. A solution to this conundrum could be to issue certificates to all students and let them negotiate with their home universities how these certificates are recognized (for example, by stating how many credit points the certificate is worth at the "main site" for reference), or to define the rules independently of the other sites and only let universities participate if they adopt these rules. In any case, treating all students in an equal manner is important for the groupwork, which in turn influences the cohesion of the community.

In retrospect, the goal to establish a community of students was met only partially, as some success factors were not applicable mainly due to technical shortcomings of the 3-D CVE framework.

4.10 Conclusions

The following paragraphs summarize the success factors and potential challenges, based on the investigation of the ShanghAI Lectures from the perspective of the involved faculty and staff, and mention possible remedies where appropriate. The aim of this section is to provide a better understanding of what constitutes a Global Virtual Lecture Hall and to aid those who want to venture into similar teaching projects.

4.10.1 Success factors

One of the major success factors of the ShanghAI Lectures is that they incorporate much of a "traditional" university setting (students attending the class together at a fixed schedule, interacting with the lecturers, solving exercises) while extending it in numerous ways, such as alleviating the restriction to physical lecture halls (with the recordings and the 3-D CVE) and making it available at a number of universities of which many did not offer such an introductory course to embodied AI before. In addition, it reduced the need for traveling for students and lecturers, resulting in a more "environmentally friendly" class.

Using standardized communication tools (e.g., the H.323 protocol for videoconferencing) and offering parts of the infrastructure – such as the screen sharing and recording facilities, the whole content of the lectures and exercises, the robot simulator, or the website – to the participating universities for free makes it easier for them to join the program: videoconferencing equipment is already present in many sites, and apart from personnel costs there is very little financial effort needed. The open availability of the main lecture and the guest talks to anyone, even without registration, added to the visibility of the project.

Because the technical infrastructure worked very well in general, some small glitches were more easily forgiven and even added to the "live feeling" of the class. Except for the technical shortcomings that caused some chagrin among the students in the first two years, the 3-D CVE was, in principle, a good addition, as it enabled more interactivity and novel educational concepts.

To have a friendly and competent support staff – in the case of the ShanghAI Lectures, mostly the helpdesk personnel at SWITCH and the local technicians – was crucial for a smooth overall experience.

Regarding the content, the ShanghAI Lectures benefitted from a subject that is particularly suited for "cool" and appealing topics to be discussed in the class, and the base lecture was not a very technical but rather a "popular science" style introduction to a certain way of looking at natural and artificial forms of intelligence. The main lecture was held by an experienced and well-known speaker, who provided an entertaining class. A variety of topics were presented in the guest lectures, which provided a broad overview of the research field and stimulated an exchange beyond not only geographical, but also topical communities. This concept of a base lecture plus guest talks that provide a broader view of the field and give examples of recent developments is definitely a success factor.

The website as a central "hub" facilitated this exchange, and publishing additional reading materials there allowed students to prepare for the class and participate more actively. Interactivity during the videoconference was stimulated by announcing some of the questions that would be posed to sites beforehand.

4.10.2 Potential challenges

The biggest challenge in global teaching is to find a common base among the different educational and organizational systems that are in place at the participating universities. In the case of the ShanghAI Lectures, most student matters (in terms of credit points, mandatory assignments, attendance control, etc.) were delegated to the individual universities. This led to some dysfunctional exercise groups, as some group members did not have the same "motivation" to contribute to the common task as the others.

Remedy: While it may alienate some potential partners, student matters could in principle be standardized and "imposed" on all participating universities. Ideally, the exact terms and conditions are negotiated *in plenum*, and cooperation agreements or contracts are signed well before the lectures begin.

Different time zones remain a major challenge. Unless students (and staff) are willing to get up very early or stay up very late, it is not possible to create a truly *global* virtual lecture hall in the sense that students from around the globe concurrently participate in the class.

Remedy: Organize the classes such that the times are suitable for most participating sites.

Depending on well-known speakers for the base lecture and the guest talks is both an advantage and a potential challenge, as it made the ShanghAI Lectures more attractive to other universities but at the same time gave them basically no control over the content of the course, making their integration into the curriculum not always trivial. Not being able to control the selection of the guest lectures led to some disappointments when the speakers did not meet the expectations.

Remedy: The negotiations mentioned above should not only focus on student matters but also include the contents of the course and the list of invited speakers. Ideally, each participating university contributes at least one guest lecture by one of its own lecturers or researchers.

The main lecturer's explicitly interactive and "informal" way of teaching was also new for some universities; students needed some time to get used to this lecturing style – again, these are cultural differences that need to be taken into account.

Remedy: Some kind of "mediation" facilities could be set up before the lectures start where everyone can participate in group activities that help overcome cultural differences (and at the same time, familiarize with the technical infrastructure).[87]

The exercises are another source of issues, especially if they depend on experimental technologies, as was the case with the 3-D CVE in the first two years: on the one hand UNIworld was too resource intensive for many sites (and difficult to use), on the other hand the potential of 3-D CVEs was not sufficiently taken into account in the actual exercises. Forcing students to use UNIworld because it was necessary for the research on virtual team behavior resulted in even less enthusiasm on behalf of the students who felt they lost a lot of time on something that was not related to the content of the course.

Remedy: Mandatory exercises should be designed around mature technologies to ensure little distraction from the tools, so that students can focus on the actual tasks at hand; potentially unstable environments can be used in optional exercises (that may yield bonus points) for those students who volunteer to test experimental technologies and concepts.

Even though the grading of the exercises was distributed among tutors from the participating sites, it required a lot of effort on behalf of the teaching assistants as they needed to familiarize themselves with the contents and grading guidelines to ensure a standardized grading scheme.

Remedy: Taking some inspiration from MOOCs, exercises could be designed such that they can be graded (semi-)automatically.

On the technical side, even though videoconferencing has been around for decades, there are still many factors that can have detrimental effects. From insufficient bandwidth (especially in the case of some one-time participants who gave a guest lecture from home) that caused interruptions of the videoconference, bad lighting in the auditoriums, to audio issues (noise or echo if several microphones are open at the same time), the ShanghAI Lectures occasionally suffered from glitches that could in principle be avoided if the technology were adaptive enough – or if the local staff knew how to operate it.

Remedy: In addition to distributing information sheets (see Appendices I and J), technical training sessions could be provided to the local staff (e.g., how to set up and operate the videoconferencing equipment), the speakers (e.g., how to prepare slides and videos for the specific setup, such as obeying the rule that movies must not be embedded but instead shown in the videoconference; how to adapt their lecturing style to the technology), and potentially also to the students (e.g., how to "behave" in a videoconference). If students are aware of the complexity of the Global Virtual Lecture Hall, technical and organizational issues are more easily forgiven.

The complexity of a project like the ShanghAI Lectures necessitates a lot of time-consuming organization. The course has to be announced, tutors have to be recruited; suitable lecture halls need to be booked; in case no videoconferencing infrastructure is available, it has to be acquired and installed; everything needs to be tested beforehand and operated during the lectures. Teaching staff need to be instructed regarding the exercises, speakers have to prepare their presentations, etc.

Remedy: The organization may be streamlined if every participating site has one local coor-

[87] A "mediation workshop" where students and lecturers would participate in group activities within UNIworld was actually part of the original design of the ShanghAI Lectures project, but not realized due to limited resources.

dinator who reports to the overall project manager. This person needs to be appointed early in the planning process and should be familiar with the local personnel and infrastructure, ideally also with the topic of the course.

4.10.3 Additional recommendations

In a live lecture, all presenters and staff should be able to cope with common issues by themselves, for example, in case of a sudden connection loss they should know how to reconnect. Everything needs to be tested – from the seemingly simple handling of a microphone to rehearsing the full presentation scenario that involves taking and releasing control of the screen sharing software, knowing which part of the presenter's area is covered by the camera, how to show videos, and how to switch between different cameras (if available). This all adds a lot of work to the faculty and staff but in the end results in a smooth and enjoyable "show" for the students. It does not have to be 100% perfect – minor "hiccups" add to the "live" character of the lectures.

Sticking to the schedule is very important, especially in the Global Virtual Lecture Hall where there are many universities participating; students may not be able to stay if a lecture lasts longer than announced.

If there is no live streaming with a feedback channel, but students have the possibility to watch the lecture recordings, there should be incentives for them to come to the lecture hall (such as the "Frame-of-Reference competition"): Interaction is very important, it should appear as a natural part of the lecture though, not "forced" upon the students (otherwise, they will not come to the lecture hall anymore). Providing relevant materials well before the lecture or guest presentation helps students to prepare and potentially come up with interesting questions. Quick polls during the lecture can be done with clicker systems or web-based survey services and provide immediate feedback to the lecturer without losing time switching the videoconference layout and turning on and off microphones.

In case the course yields credits (certificates, ECTS points, grades, etc.) these should be standardized for all students if possible. Otherwise, collaboration in the exercises or projects might not be successful because some students in one group do not need to work on the assignments. An alternative approach would be to form groups of students with identical or at least similar requirements, even though these groups might then be less "international".

Technologies such as videoconferencing, web chat, or 3-D CVEs can help facilitate the sense of belonging to a community – if they are working well. Experimenting technologies should not be part of mandatory assignments; otherwise the experience may be frustrating if students and lecturers have to use tools that do not work.

To conclude: Most of the concepts and technologies explored in the context of the ShanghAI Lectures contributed to the overall success of the lecture series in positive ways and may therefore be considered as useful components of a Global Virtual Lecture Hall.

5 Conclusions and outlook: Towards the Global Virtual Lecture Hall

In this thesis, four cases in global teaching were presented: the ShanghAI Lectures 2009 to 2012. More than one dozen different technologies and concepts were explored over the course of these four years (see 3.9) and evaluated with respect to their suitability as components of a Global Virtual Lecture Hall. Feedback from faculty and staff as well as personal observations by the author of this thesis resulted in a number of "success factors" and "potential challenges" that demonstrated the high complexity of the Global Virtual Lecture Hall as a socio-technical system (see 4.10).

The ShanghAI Lectures were not designed to replace traditional, "physical" universities but rather to enhance them with facilities to include a potentially large number of participants from different sites in the same class.

Real or virtual face-to-face interaction was an integral part of the ShanghAI Lectures, and a high level of interactivity between students and lecturers will become the defining feature of the Global Virtual Lecture Hall which differentiates it from other educational concepts such as MOOCs.[88]

To achieve this interactivity, the audience may be expanded and collaboration among the universities could be intensified.

5.1 Increasing the audience

Geographical data in access logs of the lecture repository could help identify regions where there are potentially many students interested in joining the Global Virtual Lecture Hall, which might then lead to negotiations with universities in these areas to join the academic program.

Apart from negotiating a common set of rules that apply to all participating students (see 4.10.2), it may be possible to establish an academic program or "label", supported and recognized by all universities that join the Global Virtual Lecture Hall project, and that is worth a certain number of credit points. The task of giving the base lecture could be distributed among participating universities, as could the creation of exercises and exam questions in order to create a common curriculum.

The ShanghAI Lectures were held in English only. However, language skills among students (and lecturers) vary considerably. The language barrier might eventually be overcome

[88]Of course, MOOCs have their advantages too (see 2.5). Likewise, the ShanghAI Lectures model may not be suitable for every topic; different contents require different levels of interactivity.

by using real-time translation systems, as demonstrated in 2012 (see 3.8.1), or by adding subtitles in several languages to the recorded lectures[89]. TED talks and other online repositories already offer subtitles in many languages.

To reach an even greater audience, in addition to students in the lecture halls and avatars in the 3-D CVE, the lectures could be streamed live on the internet with the option of feedback from virtually anyone by e-mail, social media (Twitter, Facebook), or – as some of these channels are not accessible or popular everywhere – special provisions on the website.

5.2 Intensifying interaction

Taking into account concepts from social psychology (see 4.9) in all planning and development stages of a Global Virtual Lecture Hall project may aid in establishing a sustainable community of students, faculty, staff, and potentially other interested participants even from outside of university.

To stimulate interactivity during the lectures, so-called "Audience Responce Systems" (ARS) may be used [She13]. These tools – physical devices or web-based services – allow students to give immediate feedback in the form of short yes/no or multiple-choice answers. For example, the lecturer could show a list of four robots and ask the students which one they would like to learn more about. By pressing a button on a special ARS device, sending an e-mail, text, or Twitter message, or selecting the respective option on a website, students submit their choice. Within seconds the lecturer sees which robot gets how many votes and can then proceed with the most popular topic.

Despite the suboptimal experiences with OWL in the first two years of the ShanghAI Lectures, 3-D CVEs could eventually become an essential part of Global Virtual Lecture Halls because they offer interesting teaching/learning techniques (e.g., manipulation of 3-D models, sharing of resources such as documents with a large audience, or the spatial arrangement of avatars and objects according to different topics in a class) and create a *sense of presence* among the participants that could not otherwise be established with traditional "2-D media" – provided that the user experience for the students and lecturers becomes as smooth and "natural" as a webcam chat via Skype, Google Hangouts, or iMessage and the course topics or exercises match the affordances of the virtual world.

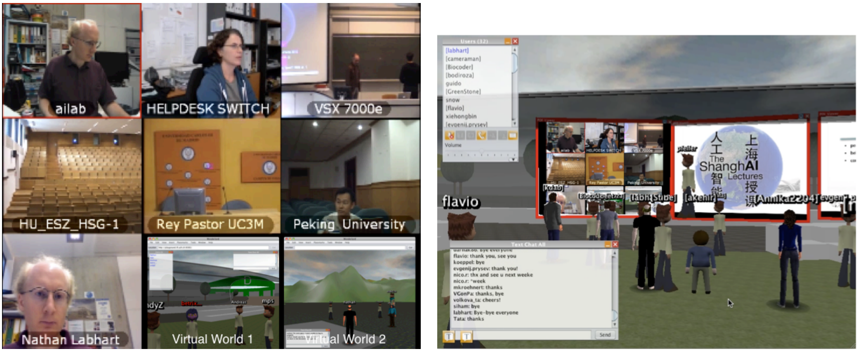
3-D CVEs are still evolving and becoming more stable, feature-rich, and open with respect to their interchangeability[90]; first steps toward this goal were already taken with the announcement of an interoperable file format [Imm10], even though it seems that so far there have not been any concrete results. Depending on the intended uses, e.g., whether the virtual world should be a collaboration tool only or also serve as a research platform, open source or commercial frameworks may be selected. Open source frameworks have recently been found "not mature enough yet to accommodate collaboration activities and allow educators to utilize them effectively" [MKT12], but a project with the goal to suggest both open source and commercial frameworks according to freely selectable evaluation criteria has already been

[89] This work may be crowd-sourced

[90] This would make it easier to change from one framework to another without having to reimplement everything.

started [EO11, Ere12].

One scenario could be to integrate the 3-D CVE with the videoconference, i.e., to provide one or several virtual meeting rooms for avatars that are connected to the MCU in the same way as "real" classrooms for students (see Figure 5.1).



(a) 3-D CVE in the videoconference

(b) Videoconference in the 3-D CVE

Figure 5.1: Bridging the videoconference and 3-D CVE (mockup).

For gatherings within the 3-D CVE, the involvement of some kind of "emotion recognition" device [KSAS+10] that measures e.g. attention levels of each student[91] could lead to changes of the virtual world. For example, if students are getting sleepy, the light in the virtual world would be dimmed, signalling to the lecturer that attention levels are dropping; on the other hand, the light levels could increase to "wake up" the students.

Data mining techniques applied to usage logs of the 3-D CVE and the community website can help identify usage patterns that may be further optimized. In addition, this data can be used to suggest additional, individualized resources and reading materials to each user, similar to recommendation systems from online retailers such as Amazon, and to identify other community members with similar interests.

To conclude: The ShanghAI Lectures project has established a comprehensive set of technical and social/educational components that may become a standard concept in higher education. Whatever the future of global teaching will be like, the author of this thesis looks forward to the next project that will be opened with the words *Good morning, good afternoon, good evening everyone – welcome to the Global Virtual Lecture Hall!*

[91] Andy Zbinden, Cornelia Setz, personal communication (2010-05-11).

Appendices

A The ShanghAI Lectures: Using Virtual Worlds for Intercultural Student Collaboration

Béatrice S. Hasler, Vania Guerra, Nathan Labhart, Andy Zbinden, and Rolf Pfeifer. *The ShanghAI Lectures: Using Virtual Worlds for Intercultural Student Collaboration.* ACM Workshop on Intercultural Collaboration, Stanford University, Palo Alto, February 2009.

The ShanghAI Lectures: Using Virtual Worlds for Intercultural Student Collaboration

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ABSTRACT

The demonstration will take place in the context of "The ShanghAI Lectures"[1], a global mixed-reality educational experiment that has three main goals: (1) Building a sustainable, global community and knowledge source in "Embodied Intelligence", a topic area of interest for an audience with widely varying backgrounds, (2) testing and refining state-of-the-art technology to enable and promote this process, and (3) piloting a platform for cutting edge research in all areas of technology-enhanced learning. These lectures are planned to be broadcast by videoconference from Jiao Tong University in Shanghai to universities on each continent. To support community formation, these institutions will join interactive videoconference sessions on a regular basis. In addition, virtual spaces will be provided to promote interaction and cooperation among participants. The communication and collaboration features of the 3D virtual environment will be demonstrated at the IWIC conference, and first experiences from a pilot study in fall 2008 at the University of Zurich will be reported.

Keywords

Global teaching, virtual worlds, intercultural collaboration

RATIONALE

At the Artificial Intelligence Lab at the University of Zurich, we have started working on a global virtual lecture series on embodied intelligence and biologically inspired robotics, exploring innovative technologies for teaching, cross-cultural collaboration, and community building. By using novel communication and information technologies, we intend to overcome the complexity of a multicultural and multidisciplinary learning context in higher education.

We aim for ten lectures which will be distributed to the participating universities via videoconference and live webcast. In parallel, there will be collaboration workshops in a dedicated virtual world setup where students from these universities work on projects. We will use Sun Microsystems' "Project Wonderland" toolkit[2] as a basis to create the collaborative 3D environment in which participants are represented as avatars. The reason for integrating virtual 3D spaces is to create a sense of social presence and a feeling of "being there" [2, 4] independently of spatial or temporal constraints for the globally distributed participants, as well as to facilitate communication and collaboration among them.

Collaboration in Wonderland: Virtual Meeting Rooms with Application Sharing Facilities.[3]

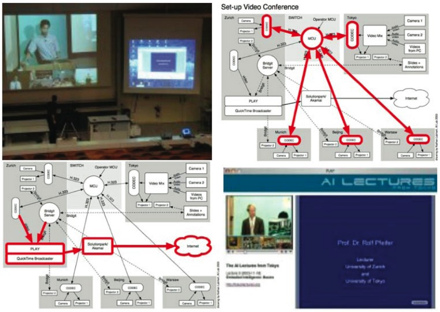
The reason for choosing Jiao Tong University in Shanghai as the host institution of the experiment is that the Chinese translation of the book "How the Body Shapes the Way We Think – a New View of Intelligence" by Rolf Pfeifer and Josh Bongard [3], which will provide the basis for the lecture series, is scheduled to appear in Spring 2009. Embodied intelligence is a topic of wide interest: First, intelligence concerns everyone. Second, embodied intelligence often leads to surprising insights (for example, how little "brain power" is required for walking, or that robots can clean up without "knowing" that they are doing so). And third, it has implications not only for science and technology (in particular robotics, artificial intelligence, behavioral science, neuroscience), but also for society at large. It will also change the way we view ourselves and the world around us. Finally, the AI Lab has much experience in establishing and using international scientific networks.

1 http://shanghailectures.org

2 https://lg3d-wonderland.dev.java.net/

3 Retrieved from: http://research.sun.com/projects/mc/images /mpk20-kap-office-entry.png

For example, five years ago we ran the "AI Lectures from Tokyo" where seven universities from Japan, China, Saudi Arabia, Poland, Germany, and Switzerland were connected via interactive videoconference for the duration of an entire semester[4]. As the technology has significantly advanced in the meantime, it seems realistic to expand this concept with a virtual-reality component[5], so that more universities and students can be incorporated.



Videoconference and Webcast System in the "AI Lectures from Tokyo" in 2003/04.

In this manner, the proposed project, "The ShanghAI Lectures", has the following general goals:

- Promoting the ideas of embodied intelligence research to a world-wide audience.
- Employing novel educational technologies for global and multicultural educational purposes, and exploring the use of existing technologies in new ways.
- Establishing a sustainable web-based knowledge network on embodied intelligence with a multidisciplinary community.
- Using this technological/educational setting as a platform for research in the fields of knowledge management, intercultural collaboration, computer-supported collaborative learning, and others.

EDUCATIONAL GOALS

Students will be immersed in a multicultural and multidisciplinary educational environment. By participating in different activities, such as expert meetings, lecture reviewing, and project-based team work, they will be encouraged to share and develop their ideas by interacting with other students, experts, and teachers. The novel virtual worlds technology will provide the context for this collaborative educational environment. In this context, teachers and students become members of a global learning community with no physical or temporal classroom limitations, while students take over an active role. Thus, we are triggering not only the knowledge acquisition process but also invoking situations where students need to develop communicative and reflective skills that enable them to build a mutual understanding among the community members (i.e. socially built meanings or conceptual artifacts [1]).

In terms of educational goals, the outlined project focuses on three distinct objectives:

- Creating a platform for the development of reflective thinking, and for exchanging ideas among members of the multidisciplinary community in order to promote networking and to foster innovation.
- Supporting the development of intercultural communication competencies to prepare students for an international work environment.
- Creating conditions for collaboration among teachers in a global learning community in order to face the complexity of an intercultural educational context.

Experiencing the various settings of this virtual environment, the participants will, on the one hand, learn about embodied intelligence. By attending lectures, students learn the conceptual basis which provides them with the framework for the development of their projects. Furthermore, they interact with experts and scientists from the area, and thus become acquainted with the state of the art and latest implementations in the field. And on the other hand, they will develop communication and teamwork skills that will enable them to interact in a multicultural and multidisciplinary world.

MOTIVATION FOR USING VIRTUAL WORLDS AS COLLABORATION TOOLS

Working in globally distributed teams presents some issues which Sun Microsystems' "Project Wonderland" attempts to overcome. The virtual worlds created with the Wonderland toolkit not only offer participants (i.e. students, teachers, and experts) the possibility to meet and communicate in virtual rooms but also to interact and collaborate by using personal representations (3D avatars) and shared applications. Communication and collaboration facilities offered by Wonderland tools include immersive audio conversation, mixed-reality communication and in-world application sharing which will play an important role in "The ShanghAI Lectures". The use of an open-source environment gives us the opportunity to develop new features which allow us to examine new options for social interaction and knowledge management. The existing Wonderland communication and collaboration tools will be adapted to support the educational goals. Some of the following potential use cases will be presented at the IWIC workshop.

4 http://tokyolectures.org

5 cf. the MiRTLE Project: http://chimera69.essex.ac.uk/User:Gardnemr/Mixed_Reality_Teaching_and_Learning_Environment

Virtual meeting rooms

Wonderland provides facilities to create different virtual rooms for group meetings during project-based student work. Additionally, in these virtual rooms, sessions before and after the lectures will be held where the students can meet experts. The times the experts are available will be scheduled such that eventually all participants - regardless of their time zone - can participate at some point. We will also provide a space for collaboration among teachers for exchanging ideas on how to adapt the educational activities to the different participating cultures.

Virtual presentations and guest lectures

By using mixed reality settings combining video streaming and virtual worlds we attempt to carry out educational real-time events such as student presentations and guest lectures. We intend to enable students from different countries to not only attend the lectures but also to actively participate, for example, by presenting their projects to other students around the world.

In-world application sharing

In-world application sharing allows participants to share the same applications for the development of an activity (for example, text processor, presentation or spreadsheet programs). These tools enable students to create a mutual understanding by graphically depicting their ideas. Students from different countries can work together in their projects directly within the virtual world.

Annotated lectures

An extended application sharing function uses screens in a virtual room where recorded videos of the lectures can be re-viewed, with a menu containing a table of contents of all the lectures. Avatars standing in front of the lecture screen may choose a lecture and view it using "stop" and "play" buttons. Next to the lecture screen, there is a separate screen, where they can make annotations or note questions when they stop the video. The screens will be coupled such that when the lecturer reviews the lectures, the annotations are associated to the particular position in the lecture. In order to get collected annotations to a particular sequence of the lecture, the lectures have to be divided into semantic segments. In addition, we will also record the students' text- or speech-based discussions (as avatars) at the very specific point in the lectures.

HOW THE TOOL WILL BE DEMONSTRATED AT THE WORKSHOP

We will demonstrate the current state of the technological development of the virtual world communication and collaboration facilities. In fall 2008 we will carry out a pilot study involving a small sample of participants. The purpose of this pilot study is to test both technological and educational settings in order to analyze the strengths and weaknesses of the virtual environment.

Screen recorded examples of in-world user interaction and initial findings of the pilot study will be available at IWIC in February 2009. The examples will be shown as short movies, and the presenter will point out potentials and challenges the in-world communication and collaboration facilities provide. Besides usability aspects, such as user acceptance and reported experiences, evaluation data will detail challenges faced in cross-cultural collaborative activities and environments, and suggest future steps.

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B The ShanghAI Lectures: Connecting Continents in Cyberspace

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The European Future Technologies Conference and Exhibition 2011

The ShanghAI Lectures: Connecting Continents in Cyberspace

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Abstract

The ShanghAI Lectures project contributes to the fundamental goal of making education and knowledge accessible to a broad interdisciplinary and intercultural audience. Deploying state-of-the-art videoconferencing technology and three-dimensional virtual environments, the project enables students and researchers from all around the globe to learn and work together.

Keywords: Global Education; Virtual Worlds; Collaborative Environments; Videoconferencing

1. Introduction

Every fall semester, the Artificial Intelligence Laboratory of the University of Zurich offers an introductory lecture series on the topic of "Embodied Natural and Artificial Intelligence" [1,2]. Since 2009 these weekly lectures have been held via *videoconference*, connecting roughly a dozen universities worldwide. Under the name "ShanghAI Lectures" (because the first series of these videoconference lectures were held from Jiao Tong University in Shanghai, China) this project enhances the lectures with a *community website and a three-dimensional collaborative virtual environment*, where students meet as avatars (virtual embodied representations of themselves) to solve exercises together.

2. Videoconference Lectures

Bringing together students and researchers with very diverse backgrounds was one of the main goals of the project. Therefore, the lectures were designed for a broad interdisciplinary audience. By broadcasting the lectures via videoconference, a number of universities could participate interactively, instead of just watching a prerecorded talk without any possibility to asking questions or providing input for discussion.

Every lecture was recorded and then published on the website (see section 3) for later viewing. There were in fact some further universities that were not able to join the live videoconference due to their time zone, so their students just watched the recorded lectures and then participated in the exercises.

2.1. Lecture Technology

We used the H.323 videoconferencing standard, a collection of protocols for transmitting audio and video, as the necessary equipment was readily available at the participating sites. To make the slides available to all sites in parallel to

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the videoconference, a screen sharing software was used (Adobe Connect). Using the SWITCHcast system, the lectures were recorded and published online. All three services, H.323, Adobe Connect, and SWITCHcast, were provided by SWITCH, the Swiss Education and Research Network (http://switch.ch).

3. Community Website

In order to support the participating students and lecturers, a dedicated website was set up (http://shanghailectures.org), which provided access to materials related to the lectures, such as the recorded talks, exercises, slides and additional reading materials (scientific papers, URLs to other pages of interest, videos, etc.), as well as some community-building features (forums, personal profile pages).

3.1. Guest Talk Repository

The actual classes were enriched with guest presentations by lecturers from the participating universities and “external” speakers, which were also recorded and added to the website, forming a publicly available repository of high-profile speakers in the area of Embodied Artificial Intelligence.

3.2. Website Technology

We used the popular open source Content Management System “Joomla” with special extensions for community building.

4. Collaborative Environment

The novel component in the ShanghAI Lectures is a three-dimensional collaborative virtual environment (3-D CVE), a virtual world that is used as a platform for the students to work together on exercises and to participate in the so-called “Discussion Sessions.”

In the exercises, groups of students had to solve assignments by manipulating 3-D models and using applications (whiteboards, PDF viewers, movie players, word processors, etc.) together. Complementing the lectures and exercises, the Discussion Sessions provided a possibility for students’ avatars to discuss topics directly with the lecturer avatar. There were even two guest presentations held in the virtual environment.

Unlike participants in a videoconference, avatars in a 3-D CVE have more interaction possibilities. For example, the abilities to move and interact in the virtual world (e.g., walk to another room for a private discussion, or manipulate a 3-D object of a robot to explain some mechanical properties) can be used as additional, nonverbal communication channels that enhance teaching and learning [3]. Voice and text chat are of course also possible in the 3-D CVE.

4.1. 3-D CVE Technology

As underlying technology we used the open source framework “Open Wonderland” (OWL; http://openwonderland.org), which is written in the Java programming language. Originally an internal project at Sun Microsystems to provide virtual meeting spaces to its employees, OWL became a popular option for educators after it was made available as an open source project. As such, it has some major advantages over commercial solutions such as “Second Life” because OWL functionality can be changed/extended to fit very specific needs.

Unlike competing platforms, OWL allows X11 based (graphical) applications to be run within the 3-D environment, enabling avatars to collaborate using office suites, web browsers, or any other program. Another important aspect of OWL is that we do not depend on a company and therefore have full control over the server installations and can be sure log files and user data are not used for commercial interests.

Having access to the log files was also a prerequisite for the large-scale international field study on avatar behavior that was conducted during the ShanghAI Lectures. More details about this study are to be found in the “Final Report,” (http://shanghailectures.org/project-report-2009).

5. Results

The ShanghAI Lectures were very well received in general, as many universities were able to participate in a lecture series they would not be able to offer otherwise, and students could broaden their horizons both on an academic as well as personal level by interacting with scholars from around the globe. In total, 421 students (bachelor, master, PhD) from 48 universities signed up on the website, over 250 students participated actively in the group exercises each year. Participants came from six continents: Asia, Africa, North and South America, Europe, and Australia.

Despite some technical issues, we believe virtual environments eventually *will* have their place in global education and collaboration because they offer interesting new teaching/learning techniques (e.g., manipulation of 3-D objects) and create a *sense of presence* among the participants that could not otherwise be established with traditional "2-D media".

We hope that as the underlying technologies evolve, the combination of videoconferencing, community website, and 3-D CVE sees its application also for other educational content in the years to come.

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C The ShanghAI Lectures: A Global Education Project on Artificial Intelligence

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Abstract: We present a global education project in Artificial Intelligence (AI) called the "ShanghAI Lectures": A lecture series held annually via videoconference among 15 to 20 universities around the globe. The lectures are complemented by a novel three-dimensional collaborative virtual environment for international student teamwork, and a web-based resource designed as a knowledge base and for community building. This paper summarizes the lessons learned from the first edition of the ShanghAI Lectures, which may guide future global teaching and learning projects of this kind.

Keywords: Global Teaching, Intercultural Learning, Videoconference, 3D Collaborative Virtual Environments
Categories: L.2.7, L.3.0, L.3.5, L.3.6, L.5.0, L.6.1, L.6.2

1 Introduction

Globalization and emerging technologies for remote collaboration have led to new developments in work and education during the last few decades, and will continue to profoundly influence working, teaching, and learning in the 21st century. Since communicating with others is no longer bound to physical co-presence, traveling is often not necessary anymore (apart from issues such as carbon footprint, increasing costs and risks). Thus, virtual collaboration across national borders is becoming increasingly popular. We present a pioneering project in academic globalization that

1 Part of this research has been presented as a conference paper entitled "The ShanghAI Lectures: A case study in global education" at the Immersive Education (iED) Summit, Boston College, Boston, MA, USA, May 13-15, 2011.

aims to prepare students for a global work environment, and to provide them with a platform for practicing the effective use of novel collaboration technologies.

The Artificial Intelligence Laboratory of the University of Zurich presented a global lecture series on natural and artificial embodied intelligence [Pfeifer, 06; Pfeifer, 07] called The ShanghAI Lectures (http://shanghailectures.org). This annual lecture series was presented for the first time in fall term 2009 from Shanghai Jiao Tong University, connecting 18 universities worldwide via videoconference. In addition to knowledge dissemination to a global audience, the ShanghAI Lectures aimed to bring students and researchers from different countries and disciplines together who otherwise would not share common activities. In order to comply with these goals, we employed a three-dimensional collaborative virtual environment (3D CVE) for international student collaboration, and designed a web-based resource as a sustainable knowledge base and platform to build an international, multidisciplinary community on embodied intelligence.

In this paper we describe the three constituents of the ShanghAI Lectures project: (1) the lectures, (2) the web-based resource, and (3) the 3D CVE, and report on our lessons learned regarding each of these components. We also present the evaluation results of students' feedback collected in a survey at the end of the lecture series in early 2010. The evaluation of this global education project not only serves as a basis for follow-up editions of the ShanghAI Lectures but also aims to provide guidance for future global education projects of this kind.

2 Lectures

The lecture series gives an overview of natural and artificial forms of intelligence and introduces the notion of "embodiment", a concept which studies the role of the body in the development of intelligent behavior. This has implications not only for science and technology—robotics, artificial intelligence, behavioral and neuroscience—but also for society at large. Therefore, the lectures are designed for a broad audience, not just engineers or computer scientists.

Most of the ten two-hour lectures were split into two parts: The first hour was reserved for the actual lecture on embodied intelligence. The second hour was filled with (usually two) guest presentations by lecturers from one of the regularly participating universities or from "one-time" participants who connected to the videoconference for giving a guest talk.

Videoconference and screen sharing were used as the main channels to enable the sites to participate in the interactive lectures. Text chat was established as a third connection for "background communication."

All lectures were recorded and made available on the project website, along with recordings of guest talks, which were either held live in one of the videoconference sessions or prerecorded and submitted for inclusion in a "talk repository" on the project website (see section 3).

2.1 Videoconferencing

Videoconferences enable participants to remotely join a common meeting or lecture, even though they are located far from each other. However, different time zones might pose a problem in planning the meeting schedule, and indeed some universities could not participate in the videoconference due to time differences.

From a technological point of view a videoconference is rather straightforward, at least in principle (see Fig. 1 for two examples of how lecture halls were set up). While several competing videoconferencing technologies are available, one of the most popular and widespread is H.323, a collection of communication protocols for handling the connection, compression and transmission of the audio and video data in a packet-based network (i.e., the Internet). One advantage of H.323 is that compatible equipment is already available in many universities, which made it easier to bring together the participants in the ShanghAI Lectures. Another advantage is that in a multipoint connection (i.e., in a meeting with more than two sites), participants with different bandwidths can connect to the same conference.

Bandwidth determines the quality of the audio and video signals that a participating site sends and receives. Sites connecting with a lower bandwidth only get a reduced video resolution and low-quality audio. High-definition (HD) videoconferencing had been introduced a few years ago. However, we decided to resort to standard definition video for compatibility reasons, as most of the participating sites did not have HD equipment or the necessary bandwidth anyway.

In a multipoint videoconference, the participants are connected via a so-called Multipoint Control Unit (MCU) that mixes and distributes the audio/video signals. The number of participants is only limited by the capabilities of the MCU, irrespective of the bandwidth available to the individual sites. The MCU also controls the screen layout the participants receive, that is, how the video frames are arranged. Three screen layouts were used for the ShanghAI Lectures: (1) during a lecture, the main speaker is displayed in a big frame with some of the other sites visible on the side and below; (2) when showing videos and animations, they are displayed in full-screen mode, effectively hiding all other sites; and (3) during discussions, the two main parties are placed next to each other, surrounded by smaller frames of the other sites.

Multipoint videoconferences raise several issues that are often neglected. Most importantly, echo canceling becomes essential. If one site does not use an echo-canceling audio system, all the other sites hear a feedback (echo). Each site is required to mute their microphones when not speaking in order to avoid audio problems in all the other sites. Although it is possible to mute sites on the MCU using a web-based interface, this procedure is too slow, especially in a discussion. Therefore we had to enforce a strict policy that all participants turn off their microphones when not talking.

Another issue lies in the fact that each time a site connects or disconnects, there is an audible signal and the screen layout updates (although it might be possible to change this behavior on the MCU). In order to avoid this disturbance, we asked all sites to connect well before the actual lecture starts. However, due to network problems, some sites occasionally “dropped out” and had to be “dialed in” again during the course of a lecture.

SWITCH (http://www.switch.ch), the Swiss Education and Research Network, provided the MCU for the ShanghAI Lectures. Their MCU can handle up to 20 concurrent users. However, three slots are normally reserved for technical purposes, so we were limited to 17 participating sites per lecture. This was no problem, as the above-mentioned 18 participating sites were not connected at the same time. About 12 sites participated regularly, one MCU slot was reserved for the recording (see 2.4 below), and the remaining slots could be used for guest presentations.

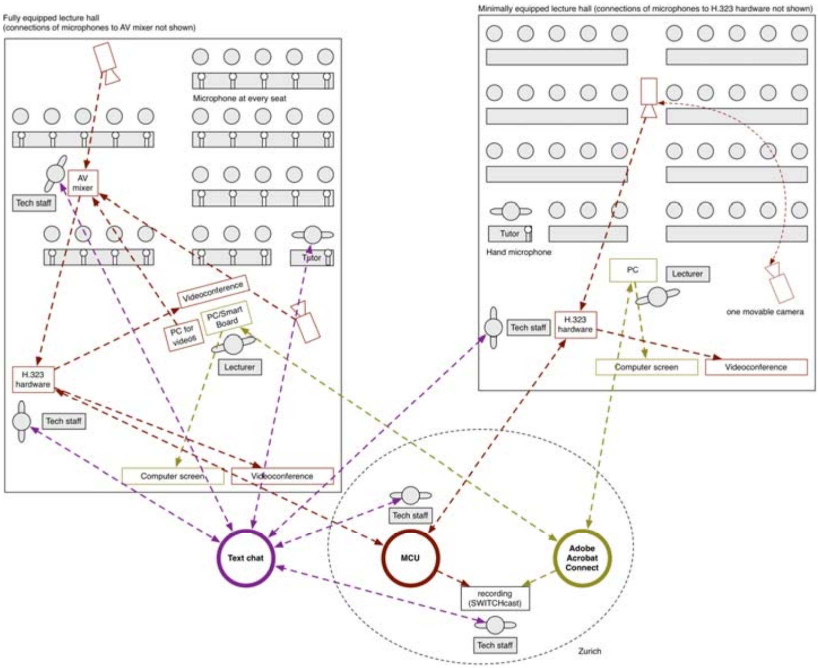

Figure 1: ShanghAI Lectures videoconference setup (left: fully equipped lecture hall; right: minimally equipped lecture hall)

2.2 Screen Sharing

All lecturers used electronic slides for their presentations, which had to be shared among the participating sites. While there is an addition to the H.323 standard that allows for parallel transmission of computer screen data (H.239), it depends on each site's equipment whether they can use this option. In order to ensure compatibility, we resorted to a software solution, Adobe Connect, that enabled all presenters to share their screens with the other participants. This software, based on the Flash plug-in for web browsers, offers much more functionality, such as text chat, whiteboards, and even webcam-based videoconferencing. However, we did not make use of these features, as we intended to keep the communication streams (i.e., videoconference, chat, etc.) separate from each other to introduce some redundancy. As with the videoconference, SWITCH provided the infrastructure (Adobe Connect server and software licenses) for the ShanghAI Lectures.

While this screen sharing solution has the advantage of being simple to setup and transparent for the users (once they are connected to the system, the lecturers can give their presentation as usual, as the software runs in the background), it can only transmit visual data at a rate of a few frames per second. In other words, animations and videos do not display smoothly and sound cannot be heard; if lecturers wish to show videos, they have to be broadcast over the videoconference channel. The system we used for recording the lectures (see 2.4 below) also made it necessary to limit the screen sharing to static images. For these reasons, we set up an audio/video mixer in the main lecture hall that connected a dedicated computer to the H.323 hardware. All lecturers were asked to send their movie files to the main site's lecture staff who then played the videos on that computer, feeding the audio/video into the videoconference.

2.3 Text Chat

We found it very important to have a communication channel open that does not interfere with the videoconference. Therefore, every participating site was required to have at least one technician online in a text chat program, so that we were able to quickly communicate in the background without disturbing the conference.

There are many commercial text chat systems available, most of which are not compatible with each other. As we did not want to force participants into one particular system, some operators had up to four chat programs open during the ShanghAI Lectures: Google Talk, Yahoo, AIM, and MSN. We did not use Skype, even though it is one of the most popular chat systems, because we wanted to keep the bandwidth requirements as low as possible.

2.4 Recording

The lectures were made available on the project's website using SWITCHcast (https://cast.switch.ch), a collection of tools and practices provided by SWITCH. Originally intended for recording normal classroom-based lectures, the SWITCHcast Recorder software combines the audio/video from the classroom's camera and microphone with the screen image from the lecturer's computer and then uploads these data streams to the SWITCHcast server for further editing. Using a web interface, unwanted scenes can be cut out, chapter markers can be added, and then the recording can be published in three formats: Streaming Flash video, downloadable QuickTime movie, and iPod-formatted "podcast" movie. Right after each lecture, we edited and published the recording, so that it would be available as quickly as possible. Some universities outside of the "compatible" time zones for real-time participation in the videoconference, followed the course of the lectures by watching these recordings and only participating actively in the international group exercises (see 4.2 below).

2.5 Evaluation Results of the Lectures

In a survey that was administered after the 2009 lecture series in early 2010, students rated a list of predetermined suggestions on how the presentation style and interactivity level of the lectures could be improved for future events. Of 282 actively participating students, roughly one third filled in the questionnaires.

63% indicated that they enjoyed attending the videoconference in their local lecture hall and that nothing should be changed regarding the presentation style of the lectures. 37% indicated that they would prefer to watch the lectures from home in real time.

Regarding the interactivity level, 54% of the students indicated that they enjoyed attending the lectures the way they were presented during the ShanghAI Lectures. 46% would have preferred more interactive lectures (e.g., to have the opportunity of asking questions during the lectures).

3 Web-based Resource

The second component of the ShanghAI Lectures project was the web-based resource, which served several purposes: A platform for community building, distribution of recorded lectures, exercises, and related materials, and a repository of guest lectures. Instead of using a learning management system like Moodle, we decided to use Joomla, an open-source content management system for regular websites, which could be adapted and extended for our purposes.

3.1 Community Platform

Our aim was to bring hundreds of students and researchers from different cultural backgrounds and academic disciplines together during the lecture series, and to enable the emergence of a sustainable community around the topics of Embodied Intelligence, Robotics, Bionics, etc., beyond the ShanghAI Lectures course. Therefore, we offered community features on the website, such as individual profile pages, and a forum where students could discuss questions and comments on the topic of the lecture asynchronously with other participating students, lecturers, and researchers (see Fig. 2). In addition to a freely accessible repository of lectures and guest talks, registered members had the opportunity to contribute to a video gallery (e.g., showing latest developments in robotics labs).

3.2 Lecture Materials

The exercises and additional materials related to the lectures, as well as recordings of the lectures themselves, were made available on the website. Students could find instructions for individual and international group exercises, the schedule and content of the lectures, as well as information on their reading assignments. We assigned the students to groups of three to five members from different universities in which they collaborated on exercises over the course of the semester. The purpose of these international group assignments was to foster cross-border collaboration between the students and to obtain data on international virtual team behavior (see section 4). Teaching assistants from the participating universities corrected and graded the group exercises. Example solutions and grading schemes were provided by the team in Zurich.

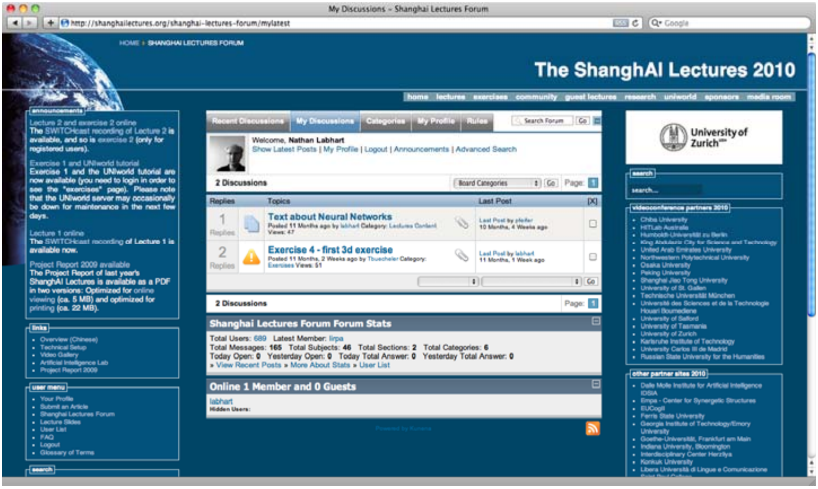

Figure 2: Community feature (forum) on the ShanghAI Lectures website (2010, look and feel identical to 2009)

3.3 Repository of Guest Talks

In addition to the videoconference-based lectures, presentations contributed by guest speakers were uploaded to the website. The idea was to create a "repository" of talks by high-profile researchers in the area of natural and artificial intelligence. While we prepared a manual for these lecturers, so that they can record and upload their talks to the SWITCHcast system by themselves, most speakers submitted prerecorded movie files that we then uploaded and published in the SWITCHcast format.

The repository of guest lectures is still growing; as of May 2012 there are more than 100 talks available.

3.4 Evaluation Results of the Web-based Resource

The same sample of students (as stated above) filled in questionnaires after the 2009 series of the ShanghAI Lectures. They rated whether they preferred to watch the recorded lectures and talks individually or together with their international team members, and which features of the web-based resource they would continue to use after the lecture series ended.

49% indicated that they preferred to watch the recorded lectures individually, and 51% would prefer to watch them with their international team members. 64% of the students indicated that they would download and watch new lectures and guest talks in the future, 28% would continue to post and respond to comments and questions in the forum, and 25% would continue to contribute to the video gallery, that is, uploading their own videos.

4 Collaborative Virtual Environment

While videoconferences and web-based platforms are not very new "tools," the novel component in the ShanghAI Lectures project is the use of a 3D CVE, a virtual world that is used as a platform for international student collaboration. The basic working principle of virtual worlds is that users log in as avatars (virtual embodied representations of themselves) from anywhere they like, provided the infrastructure (i.e., bandwidth and hardware equipment) is sufficient, and interact with others in a three-dimensional, fully configurable virtual environment. In contrast to videoconferencing, 3D CVEs provide a variety of interaction possibilities. For example, the users' virtual embodiment and the ability to move and navigate can be used as a nonverbal communication channel in parallel to voice and text chat. Interactive objects in the virtual environment can support and foster collaboration tasks and make working and learning in virtual worlds more motivating and engaging. Research has further shown that the visual character of virtual worlds increases memorability and retention [Schmeil, 09a; Schmeil, 12].

Virtual worlds, such as Second Life from Linden Labs, which were mainly developed for socializing and entertainment, are also increasingly being used for educational purposes [Hinrichs, 11]. We evaluated a number of virtual world technologies and decided to use the Open Wonderland framework (OWL; http://openwonderland.org) for several reasons that are discussed below. Originally developed by Sun Microsystems under the name Project Wonderland, OWL was released to the open source community under the new name after Oracle Corporation had bought Sun.

4.1 UNIworld

On the basis of OWL we developed a 3D CVE called UNIworld, which included a custom design of the environment (providing meeting rooms for the student groups, presentation stages, and common spaces) as well as a data acquisition system that enabled us to track avatar behavior in the virtual world. Students would log in to UNIworld in order to communicate and collaborate with their peers from participating universities all over the world.

OWL had been designed as a collaborative environment platform and therefore includes tools which are useful for team meetings and collaboration, such as a PDF viewer, whiteboard, and sticky notes. In addition, basically any X11 based application, for example, a word processor or a web browser, that is installed on the server can be used inside OWL. An application window appears as an object in the environment, and avatars can manipulate it by "taking control" in order to use the application. This enables avatars to collaborate on documents and look up information on the Internet without having to leave the virtual environment. Provided that the users wear stereo headsets, they have an immersive audio experience: An avatar's voice comes from the direction of where it is located, just as in the real world, and the volume decreases as it moves away from the listener.

Since OWL is an open source project, written entirely in the Java programming language, it has some key advantages: it is free to use, runs on all major operating systems, and can be adapted and extended relatively easily. There is a growing community of end users, many of them active in education (http://immersiveeducation.org and the newly founded European iED chapter, http://europe.immersiveeducation.org), and programmers who contribute new functionality in the form of modules (http://openwonderland.org/modules/module-warehouse). We are currently in the process of contributing our own developments for UNIworld back to the open source community behind OWL.

As OWL is still far from a final product (currently at version 0.5) it also has some limitations, namely, the maximum number of concurrent avatars on one server was not sufficient to accommodate all students. We distributed the load by setting up several identically configured UNIworld servers, and assigning every student group to one particular server. In collaboration with Henn Architekten (http://www.henn.com) and Studio-B (http://studio-b.org), the landscape of the virtual world was designed with the configuration of student teams (Fig. 3) and server limitations in mind [Schmeil, 10].

We had 18 instances of UNIworld in 2009 with five team rooms allocated to each instance. Although this has led to a reduced server load, hardly any (unscheduled) interactions took place between the students in the 3D CVE.

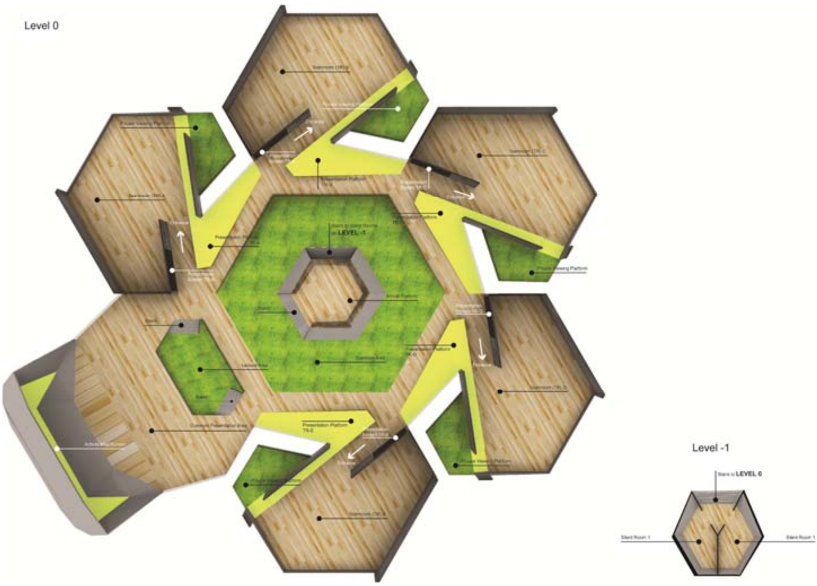

Figure 3: UNIworld design with common stage (lower left) and five team rooms

4.2 Group Exercises

UNIworld was mainly designed as a place for the student teams to work collaboratively on the exercises that accompanied the lecture series (Fig. 4). As such, the environment featured team rooms, in which the teams worked on biweekly exercises. These exercises were inspired by paper-based exercises from a former face-to-face version of the lecture and adapted for a 3D virtual world using the Avatar-Based Collaboration Framework [Schmeil, 09b]. Due to technical restrictions on the side of OWL and personnel shortage we succeeded in implementing only a limited number of engaging and novel collaborative learning tasks and activities. Nevertheless, exercises ranged from watching and annotating videos and images to staging and delivering interactive role playing performances and from voting by feet to riding on virtual robots. A small number of experimental and voluntary exercises were carried out in another open-source 3D CVE based on OpenSim.

For collaborative learning in UNIworld to run smoothly it is crucial that each participating university provides their students with access to the 3D CVE from a local computer lab, as well as technical support.

Figure 4: Group exercise in UNIworld

4.3 Evaluation Results of UNIworld

As part of the final evaluation of the 2009 series, students provided suggestions for mandatory and "nice-to-have" improvements of UNIworld in the form of free-text responses.

33% mentioned software fixes as mandatory improvements (e.g., stability and robustness of UNIworld, problems with avatar navigation, voice communication, and speed of shared applications), followed by 22% who mentioned network problems and requested lower requirements regarding Internet speed, and 11% who requested to reduce hardware requirements (e.g., graphics card) and hardware incompatibilities (e.g., microphones). 21% requested a more user-friendly interface, different or additional tools for collaboration (e.g., chat history, log of users who visited UNIworld, meeting schedule planner) or suggested improvements regarding the environment (e.g., nicer graphics, larger meeting rooms, more privacy for team meetings). 9% suggested using different media for collaboration if the task does not necessarily require a three-dimensional space. 5% had no suggestions for mandatory improvements.

As “nice-to-have” improvements, 27% requested a more intuitive user interface (e.g., easier object manipulation) and better user guides (e.g., tutorials). 25% suggested better or additional collaboration features (e.g., display of members’ time zones, screen sharing function, pointer to distant spots, and “undo” buttons). 16% requested better graphics quality. 12% suggested changes in the virtual environment (e.g., more interesting/fun places to visit, private sections for team members, more space for teamwork). 11% asked for improved avatar customization (e.g., better avatar design, more individualistic features). 5% mentioned general technical problems that need to be resolved (e.g., better speed and performance). 4% asked for more advanced and practical collaboration tasks (e.g., building and simulating robots).

5 Discussion and Outlook

The current paper presented results from the student survey of the 2009 series of the ShanghAI Lectures. More general lessons learned from the first edition in 2009 are summarized in a project report (http://shanghailectures.org/project-report-2009). We will describe our improvement measures taken for the follow-up series of the ShanghAI Lectures, and discuss alternative design solutions for similar global education projects.

5.1 Videoconferencing

The videoconference proved to be quite stable, although some sites had problems with fluctuating bandwidth or configuration issues with their local equipment, such as noisy microphones or audio feedback. Most of these problems could eventually be resolved. Nevertheless, more disciplined testing beforehand would have largely reduced the number of errors. It is important that all involved technical staff understand their roles and responsibilities, so that issues can be resolved quickly.

The interactivity level between students and the lecturer might be increased by using “clicker systems”, which enable students to send predefined annotations (e.g., “more explanation please”) or answer multiple-choice questions during the lectures in order to test their understanding. To our knowledge clicker systems have not yet been used in a videoconference-enabled global lecture hall. Using clicker systems in such a setup may cause a high technical and administrative effort. Alternatively, a messaging system (e.g., SMS or Twitter) could be used that would enable students to send (free) text questions to the lecturer. Real-time chat, however, may be challenging due to the large number of students attending the lectures and the limited amount of time available to read and respond to each question during the lectures.

In order to make the lectures more interactive, we introduced discussion sessions in the 2010 follow-up series of the ShanghAI Lectures. After every videoconference lecture, students were asked to send their questions or topics for discussion to the lecturer by e-mail. In the following week, the students did not have to come to the classroom, but instead they logged in to UNIworld and discussed these topics with the lecturer as avatars. We were expecting that avatar-based discussions would increase students' participation levels as they reduced "social inhibition thresholds"; for instance, by eliminating visible signs of hierarchy between students and lecturers in avatar appearance, and giving those students who may be afraid to speak up in a videoconference-based global lecture hall a safe environment to ask questions as avatars via text or voice chat.

5.2 Web-based Resource

As no clear tendency was found regarding students' preferences to watch the recorded lectures individually or with their international team members, both options should be offered for the recorded lectures, which are made available after the real-time event. This way the students can decide about how and with whom to watch the lectures according to their preferences. We developed a prototype of an "in-world" video player and annotation system [Hasler, 09]. This Annotated Lectures system has been specifically designed for collaborative reviewing of video-recorded lectures using stop and play buttons, to post annotations to any part of a lecture, and to reply to annotations made by other individuals or groups.

It appears that the features which are currently available on the web-based resource are not attractive enough to keep students as active members of the embodied intelligence community. The most popular features they indicated that they would continue to use were rather passive ones (e.g., downloading and watching talks). We therefore need to add more "social networking" capabilities in order to make the web-based resource not only attractive for researchers in the field, but also for students who might not yet have scientific talks or project videos to contribute. For example, the web-based resource could also be used as a platform for companies to recruit talented students for internships, and international exchange programs relevant for the target student audience could be posted on the website. In addition, students should be given the opportunity to provide more professional information about themselves (e.g., uploading their CVs).

5.3 Collaborative Virtual Environment

According to the evaluation results and feedback on UNIworld, the advantages of this 3D CVE were often not clear to the students. Many students resorted to using traditional communication channels, such as e-mail or (video) chat instead. A major lesson we learned is that all activities in a 3D CVE should motivate and engage the users and introduce innovative ways to work and learn together. We found the Avatar-Based Collaboration Framework [Schmeil, 09b] to be a useful tool to support this approach of developing memorable experiences. Ongoing research here investigates what aspects of virtual world collaboration make it truly valuable and should thus be emphasized in the development of virtual worlds and the design of collaboration.

Since the initial project in 2009, OWL has matured considerably: It became faster and more stable, and a number of modules (extensions) have been developed that address some of the shortcomings we encountered. For instance, it is now possible to watch videos within OWL, and public, private, and group chats are now available too, if needed.

6 Conclusions

In summary, the universities were excited to participate in a lecture series they would not be able to offer otherwise, and students could broaden their horizons both on an academic as well as personal level by interacting with scholars from around the globe. By the end of the 2010 series of the ShanghAI Lectures, almost 700 students (bachelor, master, PhD) from about 50 universities signed up on the website, well over 300 of them participated actively in the exercises.

The initial project was very well received, and new editions of the ShanghAI Lectures will be rolled out on an annual basis. We hope that the ShanghAI Lectures model (the combination of videoconference, web-based resource, and 3D CVE) sees its application also for other educational content in the years to come.

Acknowledgements

We would like to thank all lecturers, assistants, researchers, technical and administrative staff from more than 50 institutions who contributed to the ShanghAI Lectures, the initial project manager (Thierry Bücheler), and the main lecturer (Dr. Rolf Pfeifer, Director of the Artificial Intelligence Laboratory, University of Zurich) for making this project possible. The sponsors are listed on the project website.

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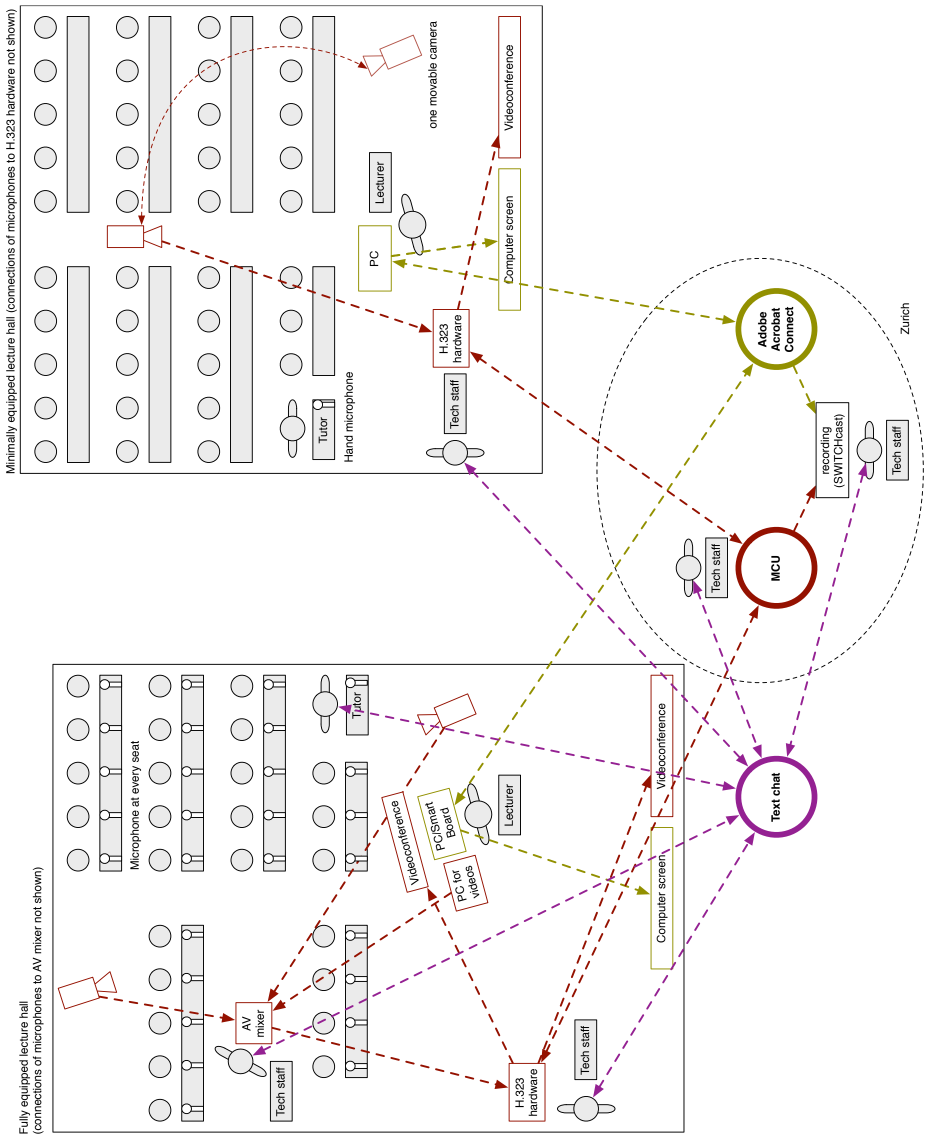
D Setup Diagram

Simplified diagram of the connections between two lecture halls and the recording infrastructure.


Minimally equipped lecture hall (connections of microphones to H.323 hardware not shown)
one movable camera
Lecturer
PC
Computer screen
Videoconference
H.323 hardware
Tech staff
Tutor
Hand microphone
Adobe Acrobat Connect
recording (SWITCHcast)
Tech staff
MCU
Tech staff
Zurich
Text chat
Fully equipped lecture hall (connections of microphones to AV mixer not shown)
Microphone at every seat
Tutor
Videoconference
PC/Smart Board
Lecturer
PC for videos
Computer screen
AV mixer
Tech staff
H.323 hardware
Tech staff

E Participants

University	Venue	2009	2010	2011	2012
Chiba University	Chiba, Japan	•	•	•	•
Northwestern Polytechnical University	Xian, China	•	•	•	•
Osaka University	Osaka, Japan	•	•	•	•
Shanghai Jiao Tong University, Minhang Campus	Shanghai, China	•	•	•	•
University of Salford	Salford, United Kingdom	•	•	•	•
University of Tasmania	Hobart, Australia	•	•	•	•
University of Zurich/ETH Zurich	Zurich, Switzerland	•	•	•	•
Technische Universität München	Munich, Germany	•	•	•	
University of Sciences and Technology Houari Boumediene	Algiers, Algeria	•	•	•	
Peking University	Beijing, China	•	•		
Sung Kyun Kwon University	Suwon, South Korea	•			•
Hosei University	Tokyo, Japan	•			
Humboldt University Berlin	Berlin, Germany		•	•	•
Karlsruhe Institute of Technology	Karlsruhe, Germany		•	•	•
Russian State University of the Humanities	Moscow, Russia		•	•	•
University Carlos III of Madrid	Madrid, Spain		•	•	•
United Arab Emirates University	Al Ain, United Arab Emirates		•		
New York University Abu Dhabi	Abu Dhabi, United Arab Emirates			•	•
Budapest University of Technology and Economics	Budapest, Hungary				•
Lodz University of Technology	Lodz, Poland				•

Table E.1: List of universities that participated in the weekly videoconference, sorted by year(s) of participation.

Name	Affiliation	2009	2010	2011	2012
Weidong Chen	Shanghai Jiao Tong University	●	●	●	
Josh Bongard	University of Vermont	●		●	
Koh Hosoda	Osaka University	●		●	
Dustin Li	Northwestern Polytechnical University	●		●	
Christopher Lueg	University of Tasmania	●			●
Eugen Elmiger	maxon motor	●			
Bernard Horan	University of Essex	●			
Auke Ijspeert	EPFL	●			
Lutz Jäncke	University of Zurich	●			
Brian David Johnson	Intel	●			
Alois Knoll	TU München	●			
Hiroshi Kobayashi/SAYA	Tokyo University of Science	●			
Hisato Kobayashi	Hosei University	●			
Sukhan Lee	Sungkyunkwong University	●			
Samia Nefti-Meziani	University of Salford	●			
Joshua Tan	Peking University	●			
Adrianne Wortzel	City University New York	●			
Hiroshi Yokoi	University of Electro-Communications	●			
Wenwei Yu	Chiba University	●			
Fabio Bonsignorio	University Carlos III of Madrid		○	●	
Claude Patrick Siegenthaler	Hosei/ETH		○	●	
Tamim Asfour	Karlsruhe Institute of Technology		●		
Louis-Philippe Demers	Nanyang Technological University		●		
Simon Grand	University St. Gallen		●		
Verena Hafner	Humboldt University zu Berlin		●		
Serge Kernbach	University of Stuttgart		●		

Name	Affiliation	2009	2010	2011	2012
Nikolaos Mavridis	UAE University		•		
Shuhei Miyashita	University of Zürich		•		
Rafael Nuñez	University of California San Diego		•		
Patrick van der Smagt	German Aerospace Center		•		
Tamás Haidegger	Budapest University of Technology and Economics			•	•
Minoru Asada	Osaka University			•	
Thierry Bücheler	University of Zürich			•	
Rüdiger Dillmann	Karlsruhe Institute of Technology			•	
Inman Harvey	University of Sussex			•	
Fumiya Iida	ETH Zürich			•	
Olivier Michel	Cyberbotics			•	
Yukie Nagai	Osaka University			•	
Toshi Nakagaki	Future University Hakodate			•	
Barry Richards	Electroimpact			•	
Alan Spreckley	ABB			•	
Craig Turnbull	Electroimpact			•	
Kevin Warwick	University of Reading			•	
Barbara Webb	University of Edinburgh			•	
Aude Billard	EPFL				•
José del R. Millán	EPFL				•
Dario Floreano	EPFL				•
István Harmati	Budapest University of Technology and Economics				•
Pascal Kaufmann	University of Zurich				•
Ning Lan	Shanghai Jiao Tong University				•
Francesco Mondada	EPFL				•
Vincent Müller	American College Thessaloniki				•

Name	Affiliation	2009	2010	2011	2012
Jamie Paik	EPFL				•
Robert Riener	ETH Zürich				•
Davide Scaramuzza	University of Zurich				•
Roland Siegwart	ETH Zürich				•
Barry Trimmer	Tufts University				•
Alex Waibel	Karlsruhe Institute of Technology				•
Vera Zabotkina	Russian State University for the Humanities				•

Table E.2: Lecturers who gave one or several guest presentations via videoconference, sorted by year(s) of participation. The empty bullet ○ denotes guest lectures held in UNIworld, the three-dimensional collaborative virtual environment.

F Respondents

This appendix lists the individuals who acted as information sources by providing their personal experiences of the ShanghAI Lectures. Most of them are faculty members (site representatives and tutors), some also acted as technical staff. In the analysis of their responses (chapter 4) they are anonymized. Notes, audio recordings, and survey data are available from the author upon request.

Interviews (marked with an "I" in the table) were held either face to fact or via Skype, surveys (marked with an "S") were conducted using e-mail and the online platform *SurveyMonkey*[1].

[1] http://www.surveymonkey.com

Name	Affiliation	Type[2]	2009	2010	2011	2012	Role	Nation.[3]	EL[4]
Cristiano Alessandro	University of Zurich	I	•		•		PhD S	IT (CH)	1
Fabio Bonsignorio	University Carlos III of Madrid	I		•	•	•	Prof	IT (ES)	2
Alvaro Castro Gonzalez	University Carlos III of Madrid	S				•	P-Doc	ES	0
Ivan Chardin	Russian State Univ. of the Humanities	I		•			P-Doc	RU	2
Weidong Chen	Shanghai Jiao Tong University	I	•	•	•	•	Prof	CN	2
Valeria Chernikova	Russian State Univ. of the Humanities	S			•	•	MAS S	RU	0
Dana Damian	University of Zurich	S		•			PhD S	RO (CH)	1
Daniel Germann	University of Zurich	S		•	•		PhD S	CH	1
Manuel Giuliani	Technische Universität München	S	•	•	•		PhD S	DE	2
José Gonzalez	Chiba University	I	•	•	•		PhD S	CR (JP)	0
Tamas Haidegger	Budapest Univ. of Technol. and Economics	S			•	•	Prof	HU	2
Koh Hosoda	Osaka University	I	•	•	•	•	Prof	JP	0
Muhammad Ilyas	Sung Kyun Kwon University	S				•	MAS S	PK (KR)	0
Tobias Klauser	University of Zurich	S			•	•	MAS S	CH	1
Manfred Kröhnert	Karlsruhe Institute of Technology	S		•	•		PhD S	DE	0
Naveen Kuppuswamy	University of Zurich	I		•	•		PhD S	IN (CH)	1
Markus Lehmann	University of Zurich	S		•	•		Tech	CH	2
Dustin Li	Northwestern Polytechnical University	I	•	•	•	•	Prof	CN	0
Suetana Loia	Northwestern Polytechnical University	S		•			MAS S	WS (CN)	0
Archie Malvar	New York University Abu Dhabi	S			•	•	Tech	PH (AE)	2
Ken Masuya	Osaka University	S				•	Assi	JP	0
Nikolaos Mavridis	UAE Univ./New York Univ. Abu Dhabi	I		•	•	•	Prof	GR (AE)	2
Samia Nefti-Meziani	University of Salford	I	•	•	•	•	Prof	GB	2

Name	Affiliation	Type[2]	2009	2010	2011	2012	Role	Nation.[3]	EL[4]
Avinash Ranganath	University Carlos III of Madrid	S				•	P-Doc	IN (ES)	2
Yuki Sasamoto	Osaka University	S		•	•		Assi	JP	0
Marcus Scheunemann	Humboldt University Berlin	S		•		•	Assi	DE	0
Sebastian Schulz	Karlsruhe Institute of Technology	I				•	PhD S	DE	2
Claude P. Siegenthaler	Hosei University	I	•	•			Prof	CH (JP)	2
Martin F. Stoelen	University Carlos III of Madrid	S		•	•	•	P-Doc	NO (ES)	1
Joshua Tan	Peking University	I	•	•			Prof	CN	2
Stefan Ulbrich	Karlsruhe Institute of Technology	I		•	•	•	PhD S	DE	1
Tatyana Volkova	Russian State Univ. of the Humanities	I			•	•	Assi	RU	0
Hesheng Wang	Shanghai Jiao Tong University	I	•	•	•	•	Prof	CN	2
Yong Wang	Shanghai Jiao Tong University	S	•				PhD S	CN	0
Wenwei Yu	Chiba University	I	•	•	•	•	Prof	CN (JP)	0
Wenxi Zhang	Shanghai Jiao Tong University	S			•	•	P-Doc	CN	0
Qian Zhao	University of Zurich	I	•		•	•	PhD S	CN (CH)	1
Xiaoyi Zheng	Northwestern Polytechnical University	S				•	MAS S	CN	0

Table F.1: List of respondents, sorted by name.

[2] Type indicates whether an interview (I) was conducted or whether an online survey (S) was filled in.
[3] Two-letter country codes according to ISO 3166-1; if a national of one country is living or working in another, the latter is added in parentheses.
[4] EL = Experience Level: 0 for no prior experience; 1 for passive use of teleteching technologies; 2 for active use.

G Information for participating universities

This document, written together with Rolf Pfeifer, was sent to all participating sites in 2012 to give an overview of the course in terms of contents, language, requirements, textbook, etc. A similar document was sent to the participants in 2009, 2010, and 2011, respectively.

The ShanghAI Lectures 2012

Information for participating universities (version 2012-07-31)

Type of lecture:

Interactive lecture/discussion series, held via videoconference, with a number of guest presentations. Students are expected to actively participate in discussions and surveys during the class. The lectures are complemented by teamwork exercises; teams consist of three to five students from different universities.

Content:

Intelligence, natural and artificial, with a focus on the concept of embodiment ("Embodied Intelligence").

While in the classical approach "intelligence" was viewed essentially as information processing taking place in the brain, more recently the notion of embodiment, i.e., the idea that intelligence is emerging from a complete organism interacting with the real world, has been gaining increasing acceptance. As a consequence, intelligence is no longer a matter of the brain only, but of the interplay of brain, body (morphology and materials), and the environment.

The implications of an embodied view on intelligence are not only of a scientific nature but lead to a completely different way of how we view ourselves and the world around us. Examples and illustrations will be taken from humans, animals, and engineering (robotics in particular) and are intended to demonstrate that things can always be seen differently from what we would normally expect. Using the method of "understanding by building", the lectures provide a set of design principles that on the one hand enable a better understanding of biological systems, and on the other provide heuristics for designing artificial ones, in particular robots. The argument is based largely on the notions of time scales (here-and-now, ontogenetic, phylogenetic), complex dynamical systems, self-organization, and emergence.

The theoretical ideas will be illustrated with many examples and case studies from biology (humans, animals) and from engineering, in particular robotics. The lectures will be complemented by a series of exercises designed to deepen the understanding of the materials presented.

Topics:
How to study intelligence? Natural vs. artificial intelligence. Classical approaches to cognitive science and their problems. Theoretical foundations of embodiment. Design principles for intelligent systems at different time scales. Learning and development, artificial evolution and morphogenesis. Principles for collective intelligence. Modular robotics. Application of principles to ubiquitous computing, business, human memory, and robots in everyday life.

> For latest updates regarding the syllabus and the guest lectures, please check out the project website at http://shanghailectures.org regularly.

Dates and Times:	First lecture: 27 September 2012, last lecture: 13 December 2012. The program is available at http://shanghailectures.org/lectures The lectures take place from 09:00–11:00 Zurich local time, which corresponds to 07:00–09:00 GMT until 18 October 2012 (due to Daylight Saving Time) and 08:00–10:00 GMT from 1 November 2012. See separate table for other time zones.
Lecturers:	Main lecturer: Prof. Rolf Pfeifer, University of Zurich. Guest lecturers from several universities.
Language:	English (textbook also available in Chinese and Japanese; Arabic translation in preparation). For active participation in the lectures and exercises, good mastery of English is a prerequisite.
Educational level:	Advanced Bachelor, Master, or PhD students from all disciplines (computer science, engineering, biology, neuroscience, psychology, natural science; no prior training required, but basic knowledge of computer science will help)
Credit/effort (University of Zurich):	6 ECTS points: Attending the lectures (2h/week), watching recorded lectures (1h/week), reading assignments (2h/week), solving exercises (2h/week). Variable study time for final examinations. *Your local rules may differ – you are free to define the requirements (e.g., whether or not a final exam is necessary) for your students. Exam materials can be provided, if needed.*
Exercises:	Exercises will be distributed via the website. Students who want or have to participate in the exercises need to register (free) during a specified time period, which will be announced in the first lecture. Most exercises require teamwork with students from other universities (e.g., discussing with peers, developing a simulation model, remotely controlling a robot, exchanging ideas). Some exercises will require the robot simulation software Webots which will be made available to the participating students free of charge during the course of the lectures, courtesy of Cyberbotics Ltd. There will be *optional* exercises/hands-on projects (robot competition) that involve additional software and hardware.
Requirements for credits (University of Zurich – you are free to adapt these requirements to your local rules):	Students need to achieve ≥50% of the mandatory exercise points in order to be admitted to the end-term exam. The final mark will be based on that exam, not on the exercise points. All students who successfully complete the course will receive a certificate. *Your local rules may differ. Please note that due to the teamwork nature of the exercises, all students in one group are supposed to contribute to the group's overall score.*

Requirements for students:

- Active participation in the videoconference: Students are encouraged to ask questions during the class; conversely, the lecturer may address the connected sites and expect short feedbacks. In addition, every week students from one or several sites are invited to give a short presentation on a selected topic.
- Readiness to work in intercultural teams, i.e., with students from other countries and with different scientific backgrounds, organizing their work (respecting different time zones) by themselves.
- Participation in an online survey approx. 3 weeks after the lectures.
- “Getting your hands dirty”: Some exercises involve physical robots, which means tinkering with glue guns, sticky tape, etc.

Requirements for faculty or institute:

- Provide credit points or some other form of acknowledgment to your students who pass the course *(depending on your local rules)*.
- Classroom equipped with H.323-compatible videoconferencing facilities (see separate document for more details).
- One main contact person at your university (professor, assistant, deputy) who supervises the local team.
- Professor or assistant who moderates the lectures in the classroom during the videoconference.
- One or several teaching assistants (TAs) who are familiar with AI/Robotics. These TAs will be assigned to 4 to 5 teams and are then responsible for marking the exercises submitted by “their” teams in a timely manner (based on guidelines and example solutions provided by the AI Lab’s TAs in Zurich).
- Technical staff to handle the videoconference in your lecture hall.
- For the hands-on robotics project: One or several TAs, ca. US$ 140–180/EUR 110–140 per kit for materials (see separate documents).

Textbook (compulsory):

Rolf Pfeifer, Josh Bongard:
How the Body Shapes the Way We Think. MIT Press 2007.

Also available in Chinese:
身体的智能 — 智能科学新视角。北京：科学出版社 2009。

Also available in Japanese:
知能の原理 - 身体性に基づく構成論的アプローチ共立出版 2010。

Arabic translation scheduled to appear in 2012.

Complementary reading:

Rolf Pfeifer, Christian Scheier:
Understanding Intelligence. MIT Press 2000.

Also available in Japanese:
R. Pfeifer, C. Scheier: 知の創成。共立出版 2001。

For further information, please contact Nathan Labhart <labhart@ifi.uzh.ch> (project coordinator) or Rolf Pfeifer <pfeifer@ifi.uzh.ch> (lecturer).

H Dates and times

This document was sent to all participating sites in 2012 to point out the time differences, especially for those sites that do not observe daylight saving time. A similar document was sent to the participants in 2009, 2010, and 2011, respectively.

ShanghAI Lectures 2012 – Dates and times

Reference time: Zurich (CET). Please note the change in time (yellow) at certain sites due to the switch from daylight saving time.*

Every lecture lasts for approx. 120 minutes, including breaks. The final lecture may last longer (up to 180 minutes).

The lectures start at 09:00 Zurich time sharp. Please connect to the videoconference **at least 30 minutes early** to ensure that we can start on time.

		UTC/GMT	London	Algiers	Zurich	Moscow	Abu Dhabi	Shanghai	Osaka	Hobart
2012-09-20	**General Rehearsal**	07:00	08:00	08:00	09:00	11:00	11:00	15:00	16:00	17:00
2012-09-27	**Lecture 1**	07:00	08:00	08:00	09:00	11:00	11:00	15:00	16:00	17:00
2012-10-04	**Lecture 2**	07:00	08:00	08:00	09:00	11:00	11:00	15:00	16:00	17:00
2012-10-11	**Lecture 3**	07:00	08:00	08:00	09:00	11:00	11:00	15:00	16:00	18:00
2012-10-18	**Lecture 4**	07:00	08:00	08:00	09:00	11:00	11:00	15:00	16:00	18:00
2012-10-25	**no lecture, time for projects/exercises/homework**									
2012-11-01	**Lecture 5**	08:00	08:00	09:00	09:00	12:00	12:00	16:00	17:00	19:00
2012-11-08	**no lecture, time for projects/exercises/homework**									
2012-11-15	**Lecture 6**	08:00	08:00	09:00	09:00	12:00	12:00	16:00	17:00	19:00
2012-11-22	**Lecture 7**	08:00	08:00	09:00	09:00	12:00	12:00	16:00	17:00	19:00
2012-11-29	**Lecture 8**	08:00	08:00	09:00	09:00	12:00	12:00	16:00	17:00	19:00
2012-12-06	**Lecture 9**	08:00	08:00	09:00	09:00	12:00	12:00	16:00	17:00	19:00
2012-12-13	**Lecture 10**	08:00	08:00	09:00	09:00	12:00	12:00	16:00	17:00	19:00

* Check http://www.timeanddate.com for additional information

Nathan Labhart, labhart@ifi.uzh.ch · 2012-07-09

I Technical Overview

This document was sent to all participating sites in 2012 to give an overview of the technical setup and explain the connection procedure. A similar document was sent to the participants in 2009, 2010, and 2011, respectively.

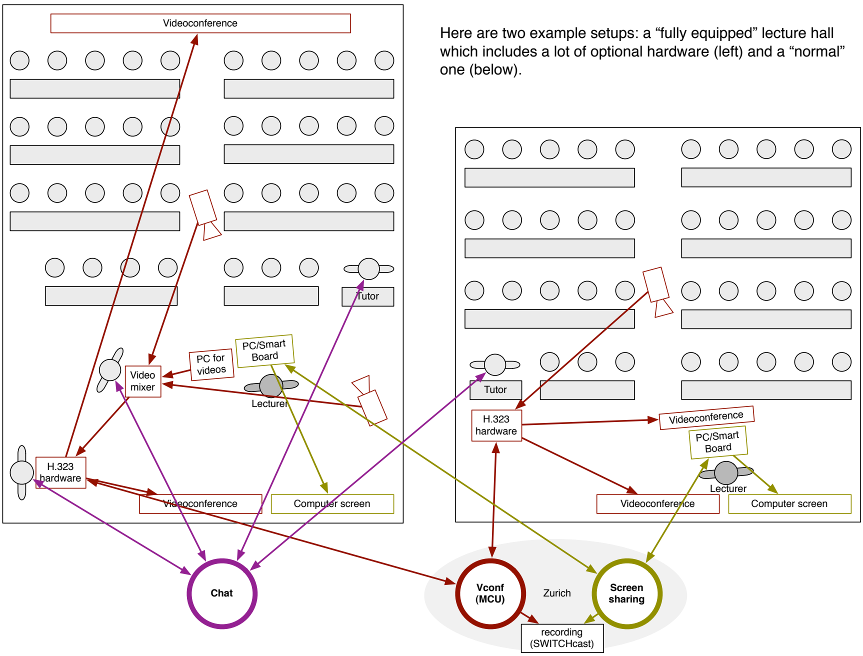
ShanghAI Lectures 2012 — Technical Overview

These three communication channels are used during the lectures:

Videoconference: IP based videoconference using the H.323 standard. Each lecture room is connected to the MCU (Multipoint Control Unit) provided by SWITCH in Zurich. In the videoconference channel, the sites can see and hear each other, and videos can be shown.
➔ In order to participate, every site needs an H.323 compliant device/setup, such as hardware from Tandberg or Polycom; software solutions are not recommended.

Screensharing: Presentation slides, e.g., Powerpoint, Keynote, shared via Adobe Connect, hosted at SWITCH in Zurich (i.e., you don't need any licence for Adobe Connect). Only for static content, please do not embed videos in your slides!
➔ In order to participate, every site needs one computer with a web browser and Flash plugin. This computer should be used for the presentations only, not for other tasks/channels such as chat.

Chat: Low-bandwidth text communication "behind the scenes" among assistants and technicians before and during the lectures, using free instant messaging systems (MSN, Google, Yahoo, AIM).
➔ In order to participate, every site needs to provide the chat name of an assistant or technician and make sure this person is online, using a dedicated computer, during the videoconference.



Here are two example setups: a "fully equipped" lecture hall which includes a lot of optional hardware (left) and a "normal" one (below).

Setup:

At least 30 minutes before the lecture begins, the assistants/technicians at every site connect to the

- **Videoconference:** via H.323 "dial-in": 0041 44 250 96 36 or via IP: 130.59.10.80 (connect and then enter meeting #36).
- **Screensharing:** https://collab.switch.ch/shail2012 (enter as a guest, providing your name or the name of your university — you might have to wait a bit, as I need to manually "let you in")
- **Chat:** Google Talk (nathan.labhart@gmail.com), AIM/iChat (nlabhart@mac.com), Yahoo (nathan.labhart@yahoo.com), or MSN/Live (nathan.labhart@live.com)

Together we make sure the videoconference and screensharing connections are working well, so that everything is ready by the time the class starts.

During the lecture, technical questions can only be discussed in the text chat, so that the videoconference is not disturbed. Every lecture will be recorded and made available on the project website, so in case a site "drops out" of the conference, the students can access the content afterwards.

Requirements for participation in the ShanghAI Lectures:

Videoconference:

- bandwidth: 100Mbit/s (the videoconference channel alone requires at least 768 kbit/s), make sure there are no issues with NAT, routers, firewall, etc.!
- H.323 compatible videoconferencing equipment
- one camera facing the lecturer(s)
- one projector/screen (behind the lecturer, visible for local audience)
- audio system (loudspeakers, microphones/headset for lecturer). *Important: if using microphones, the H.323 equipment has to be configured with decent echo canceling. Make sure to mute your microphones or audio-out port in the videoconference when you are not talking in order to avoid audio issues such as echo or noise.*
- *optional:* additional cameras, e.g., one camera facing the audience
- *optional:* a computer for playing videos, of which the video/audio signal can be fed into the H.323 unit (requires a video/audio mixer to switch between the camera and computer signals)
- *optional:* one monitor for the videoconference channel (for the lecturer to see the other sites)

Screensharing:

- one dedicated computer with a web browser and Flash plugin (necessary for Adobe Connect)
- screen resolution has to be 1024x768 pixels (the screensharing is optimized for this resolution)
- one projector/screen for the screensharing channel (behind the lecturer, visible for local audience)
- *optional:* SMART Board or other means for the lecturers to annotate their slides

Chat:

- one computer in the lecture room with one person online in one of the following instant messaging programs: Google Talk, AIM/iChat, Yahoo, or MSN/Windows Live. This *must not* be the computer used for screensharing, otherwise chat messages will interfere with the presentation.

Please note that it is ABSOLUTELY MANDATORY to be online in one of these chat programs during the videoconference! If a site is not reachable by text chat (except for technical reasons, of course), we cannot allow it to participate in the lecture. Text chat is REQUIRED for “background communication” in case of issues with the videoconference or screensharing (e.g., to announce alternative connections).

To-Dos for lecturers and assistants/tutors/technical staff:

- Check the SWITCH website regarding more information about videoconference requirements and recommendations: http://www.switch.ch/point/documentation/

- Install and test Adobe Connect on the computer(s) used for the presentations early enough, not a minute before your presentation (please use this website for testing your computer: https://collab.switch.ch/common/help/en/support/meeting_test.htm).

- The screensharing is optimized for a screen resolution of 1024x768 pixels. Please set your display to this size; otherwise your slides may look distorted (e.g., if you have a widescreen display).

- When designing your slides, set their size to 1024x768 pixels (or another 4:3 format). Use large font sizes, as the slides will be scaled down in the recording and small fonts may not be legible anymore.

- *Make sure the presentation slides do NOT contain any videos*. Because of the very low framerate in the screensharing system, videos and animations have to be shown in the videoconference channel, not in Adobe Connect. If you do not have an audio/video mixer, please make your videos available to Nathan *at least 24 hours before your presentation*, so that we can feed them into the videoconference when you give your talk. Use FTP, Dropbox, or send physical media (no e-mail).

- Do not upload your slides into Adobe Connect; use the screensharing option instead. Uploading slides into Adobe Connect may change their layout (fonts, paragraphs, colors).

- When you give a presentation, do not wear striped or patterned clothes, as this may cause flicker in the videoconference (Moiré patterns). Plain-color clothes work best.

- Test your slides, the videos, and the audio/video installation in the lecture hall beforehand.

- Reserve the lecture hall one hour before the lecture, in order to set up the equipment (if not already installed permanently), and connect AT LEAST 30 minutes before the lecture begins, so that there is enough time to fine-tune the videoconference connections with the other participants.

- Make sure that one technician or tutor/teaching assistant is online in the text chat during the whole videoconference, so that we can communicate “in the background” if there is a problem. *Again, if your site does not connect in text chat, we will not allow you to participate in the videoconference.*

In case of questions, please feel free to contact Nathan Labhart at labhart@ifi.uzh.ch.

J Technical Information for Guest Presenters

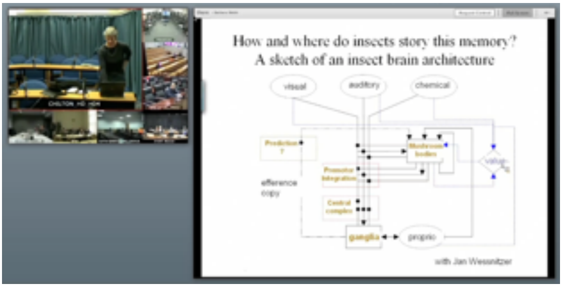
This information sheet was sent to all guest speakers in 2012 to point out the necessity of keeping the videos separate from the slides (the low frame rate in the screensharing channel was not suitable for moving images) and provide instructions on how to use the screensharing system.

The ShanghAI Lectures
Technical Information for Guest Presenters

There are two communication channels relevant to your guest lecture: Videoconference and screensharing (for your slides).

Hopefully, technicians at your site will take care of the **videoconferencing** setup and provide you with the necessary equipment (microphone, screen, etc.) so that you can just talk to the local audience or into the camera, or both. However, in the videoconference the other participating sites can only see and hear YOU, not your slides.

In order for the other sites to also see your slideshow, we use the **screensharing** channel. This is basically a small software that runs in the background and sends whatever is displayed on your screen to the other participants.



Please note the following points:

- The screensharing channel is optimized for a resolution of 1024x768 pixels. If possible, please set your screen resolution to this size (otherwise the slides may appear stretched at other sites).

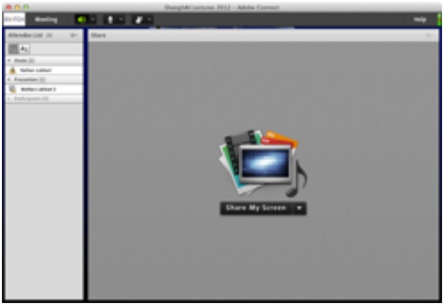
- The software requires a stable and relatively fast connection to the internet, therefore we recommend using tethered internet (in some rare cases, the software loses the connection when on a wireless network).

- Because of the low framerate in the screensharing channel, videos and animations have to be shown in the videoconference instead. If you want to show videos, please make them available to Nathan at least 24 hours before your presentation, so that we can feed them into the videoconference from Zürich when you give your talk. Use FTP, Dropbox, or send physical media (no e-mail). When it's time to show a video, just say something like "play video <file name> now" and we will feed the respective movie (including audio) into the videoconference. You can continue talking while the video is playing.

- Well before giving your talk, please download and install the "Adobe Connect Add-In" from here: https://collab.switch.ch/common/help/en/support/downloads.htm

- A few minutes before your presentation, open this website https://collab.switch.ch/shail2012 in your browser and enter as a "Guest", providing your name. After a few seconds you are granted access and see someone else's computer screen being shared.

- When it is your turn to start your presentation, the other screen disappears and you see a button "Share My Screen". If you have more than one screen (e.g., an external monitor or projector), you can select which screen to share: make sure to share the one on which your slides are visible. Select "Desktop" and click "Share" – now all other sites can see whatever is on your screen.



- Now switch to your presentation program (Powerpoint, Keynote, Adobe Reader, …) and start the slideshow. While you give your presentation, Adobe Connect sends your screen image to the other sites, automatically updating it as you switch to the next slide. You can give your presentation as if you were showing your slides on a local projector.

- Once your presentation is over, switch to the Adobe Connect program and click "Stop Sharing", then quit the screensharing channel by selecting "Exit Adobe Connect" from the "Meeting" menu.

- Do not upload your slides into Adobe Connect; use the screensharing option instead. Uploading slides into Adobe Connect may change their layout (fonts, paragraphs, colors).

- When you give a presentation, do not wear striped or patterned clothes, as this may cause flicker in the videoconference. Plain-color clothes work best.

- If possible, test your slides, the videos, and the audio/video installation in the lecture hall beforehand. Feel free to contact Nathan Labhart at labhart@ifi.uzh.ch to schedule a test connection.

We're very much looking forward to your guest presentation in the ShanghAI Lectures – thank you!

K Design principles for the Global Virtual Lecture Hall

Drawing inspiration from the "Design principles for intelligent agents" [PS99, PB07] we present a set of principles, based on our experiences with the ShanghAI Lectures and supported by the research outlined in this thesis, that may aid in understanding the underlying mechanisms of a Global Virtual Lecture Hall and at the same time serve as guidelines for those who want to venture into the field of global teaching.

While their applicability to educational projects in areas different from Embodied Artificial Intelligence has yet to be demonstrated, we think that the present set of design principles provides a solid starting point for further research in Global Teaching.

Three constituents Designing a course for the Global Virtual Lecture Hall involves the following constituents: (1) definition of the content and desired outcome, (2) definition of the involved sites and persons, and (3) definition of the technology.

Just like a regular lecture, a course in the Global Virtual Lecture Hall should have clearly defined contents, e.g., a textbook and additional reading materials. Selecting this content and defining exercises aids in setting the learning outcome, i.e., what students should take home from attending the course. Depending on the content, partner institutions can be selected – it makes little sense to arbitrarily invite other universities; ideally, the participating sites are already offering local classes that are then complemented by the course in the Global Virtual Lecture Hall. Defining the technology enables the participants to connect to the Global Virtual Lecture Hall in a standardized way which reduces the need for technical support.

Complete course The complete course principle states that when designing courses for the Global Virtual Lecture Hall we must think about the complete project being deployed in the real world.

If possible, all aspects of the Global Virtual Lecture Hall – lecturer(s), contents, technologies, partners, schedule, etc. – should be looked at not separately, but as a whole entity that is embedded in the real, "messy" world. If one only looks at individual components without keeping in mind the bigger picture, the course can easily become incoherent. For example, if guest speakers do not take into account the knowledge level of the students (which in turn is dependent on the schedule of the main lecture), some guest presentations might not be suited for the audience (see 4.5).

Cheap design The principle of cheap design states that if courses are created to exploit the properties of the technology and the characteristics of the interaction with the educational environment, their design and planning will be much easier, or "cheaper".

When planning a course in the Global Virtual Lecture Hall, one does not need to start from zero. The "ecological niche" (i.e., the worldwide/distributed educational environment) already has a number of inherent features with which one has to comply, e.g., different time zones, curricula and semester dates, and technical infrastructure. However, these may be *exploited* such that the organization and deployment of the course becomes easier. As a concrete example, H.323-compliant videoconferencing infrastructure is available at most universities, which makes it easier to design the Global Virtual Lecture Hall with this specific technology as a basis. In turn, the capacity of the H.323 MCU limits the number of participants, but this can again be used as an advantage – as shown in 3.4.1, a relatively low number of concurrent sites allows for better interactivity and lessens the "cognitive load" of the lecturer.

Redundancy The redundancy principle states that a Global Virtual Lecture Hall must be designed in such a way that (a) its different subsystems function on the basis of different educational or technical processes, and (b) there is partial overlap of functionality between the different subsystems.

In the ShanghAI Lectures three communication channels were used during the videoconference (see 3.4): The videoconference itself, screen sharing, and a text chat system for background communication. While these channels were kept separate most of the time, they introduced some redundancy into the system: If for example one site lost the videoconference connection to the MCU, text chat made it possible to resolve the technical issue; and when the MCU stopped all connections because the scheduled time was up (see 3.6.1), the screen sharing channel could be used to make an announcement to all sites.

On the educational side, different ways were provided to the students to understand the topics, such as the 3-D CVE, regular lectures via videoconference and their recordings, textbooks and further reading materials, exercises (both theoretical and hands-on), and in some cases individual coaching by local tutors.

Content-technology coordination The principle of content-technology coordination states that through content-technology coordination structured learning is induced.

In a Global Virtual Lecture Hall, technology very much influences the learning process of the students. It is therefore crucial that technology used to transport the content is matching the content itself (see also the "Three constituents" principle). By interacting with the environment (consisting of the technological infrastructure, the social setting, and the educational contents), students cannot avoid to learn something.

Educational balance The principle of educational balance has two parts. The first states that given a certain learning environment, there has to be a match between the complexity of the course's content, technical and organizational properties. The second aspect is closely related to the first; it states there is a certain balance or task distribution between course structure, technology, organization, and the educational environment.

For a simple "step by step course on programming", a simple video-segment course à la MOOC is useful; for a course like the ShanghAI Lectures which is more about teaching new ways of thinking, more technical and organizational efforts are required.

Another example: Even though the tasks that were created to be solved in the 3-D CVE would take advantage of the features inherent to three-dimensional environments (see 3.5.4), many could not be implemented as planned, which led to an educational imbalance – students felt distracted by the 3-D features, rather than supported by them, and many resorted to more traditional means of communication for their collaborative efforts.

Parallel, loosely coupled processes The principle of parallel, loosely-coupled processes states that the Global Virtual Lecture Hall is emergent from a large number of parallel processes that are often coordinated through communication, in particular via the communicated interaction within the educational environment.

A number of "features" of the ShanghAI Lectures were not predefined but emerged during the course of the lecture series, such as the use of the screen sharing system as a backup communication channel in case of videoconference interruptions, switching the screen layout during interactive discussions, or playing the "trailer" to mark the end of a session. Many of these adaptations were suggested by individuals, communicated by text chat, e-mail, or in the videoconference.

Value The value principle states that a Global Virtual Lecture Hall is equipped with a value system which constitutes a basic set of assumptions about what is good for the students, faculty, and staff.

This leads to the question of what the individuals will do – for example, some students only want to collect credit points and therefore fulfill only the minimum requirements. Others find it exciting to interact with peers and at the same time learn something about AI; these students participate more actively, perhaps even by becoming tutors in subsequent years.

Some lecturers may see the ShanghAI Lectures as simply another means to present their research, while others take advantage of the Global Virtual Lecture Hall by actively requesting feedback from the audience and continuing the discussion on the website.

Integration of time scales Many time scales need to be integrated in one course.

Planning a lecture series that involves universities from around the globe makes it necessary to take into account the potentially different semester dates and curriculum schedules ("university time scale"). On this scale, the dates and times (considering different time zones) for the lectures need to be defined such that faculty, staff, and infrastructure are available. As an example, many universities do not provide technical support outside of regular office hours.

Assignments have to be created such that they can be solved within an "exercise time scale" (in the case of the ShanghAI Lectures, usually two weeks).

Finally there is the "lecture time zone", the two or three hours during which the actual contents are presented and discussed and potentially complemented by guest presentations. On this level the smooth interplay of technological and social protocols is most important. For example, there have to be mechanisms to signal speakers who exceed their allotted time slots to come to an end, which may involve both technical means (a message popping up on the screen, or a light blinking) and social actions (a moderator interrupting the speaker politely).

Development as an incremental process The development of a Global Virtual Lecture Hall is an incremental or historical process, building successively on top of what has already been achieved. The ShanghAI Lectures, as an example, benefited from previous projects such as the AI Lectures from Tokyo (see 2.8.1) and the AI-Days (see 2.8.2), and the experiences from one year of ShanghAI Lectures influenced the organization and deployment of the following year.

Social interaction Content-technology coordination combined with social interaction provides the most powerful engine for learning. In the Global Virtual Lecture Hall interaction is a key element, as it allows lecturers to get immediate feedback on whether students understood a concept, and students have the chance to discuss questions with guest lecturers. In addition, a Global Virtual Lecture Hall should provide several tools for communication, such as a website with forums, messaging and chat facilities, and collaborative environments.

Design for emergence Find local rules of interaction that lead to desired global learning patterns.

For example: One of the group exercises originally planned for the 3-D CVE, where one student would be "inside" a robot, acting solely on its sensory inputs, while the other students would observe the robot's behavior from an outsider perspective (see 3.5.4) did not explicitly state the goal to introduce the "Frame of reference" problem, but was set up such that the understanding of this concept would emerge from discussing the students' different observations.

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Curriculum vitae Nathan Labhart

Education

01/2005–06/2013	Assistant/doctoral student University of Zurich (UZH), Faculty of Economics, Business Administration and Information Technology, Department of Informatics, Artificial Intelligence Laboratory (AI Lab)
10/1998–12/2004	Master of Arts, UZH (Mass Communication, Computer Science/Artificial Intelligence, Computational Linguistics)
10/1996–08/1998	Base studies in Computer Science, ETH Zurich (no degree)
08/1992–07/1996	Matura Type C, Kantonsschule Baden (Academic Upper Secondary School)

Teaching experience

Fall 2012	The ShanghAI Lectures 2012/Introduction to Artificial Intelligence
Fall 2011	The ShanghAI Lectures 2011/Introduction to Artificial Intelligence
Fall 2010	The ShanghAI Lectures 2010/Introduction to Artificial Intelligence
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Fall 2008	Introduction to Artificial Intelligence
Summer 2008	Seminar «Robots: Theory and built from scratch»
Fall 2007	Introduction to Artificial Intelligence
Summer 2007	Seminar «Robots: Theory and built from scratch»
Winter 2006	Introduction to Artificial Intelligence
Summer 2006	Seminar «History of AI»
Winter 2005	KV Artificial Intelligence
Summer 2005	Neural Networks

Publications

Nathan Labhart, Béatrice Hasler, Andy Zbinden, Andreas Schmeil (2012): *The ShanghAI Lectures: A Global Education Project on Artificial Intelligence*. Journal of Universal Computer Science, Vol. 18 No. 18, pp. 2542–2555.

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Béatrice Hasler, Vania Guerra, Nathan Labhart, Andy Zbinden, Rolf Pfeifer (2009): *The ShanghAI Lectures: Using virtual worlds for intercultural student collaboration*. ACM Workshop on Intercultural Collaboration, 20–21 February 2009.

Nathan Labhart, Shuhei Miyashita (2007): *Adaptation of a distributed controller depending on morphology*. Proceedings of the 12th Artificial Life and Robotics (AROB), Beppu, Japan, pp. 454–457 (DVD).

Nathan Labhart, Shuhei Miyashita (2006): *How Morphology Affects Learning of a Controller for Movement*. Proceedings of the 50th Anniversary Summit of Artificial Intelligence (ASAI50).

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Awards

Young Author Award, 12th International Symposium on Artificial Life and Robotics (AROB), January 2007, Beppu, Japan

Presentations (excerpt)

10. 01. 2012	*ShanghAI Lectures*. Webinar, University of Zurich / SWITCH (Adobe Connect DACH User Meeting).
16. 11. 2011	*ShanghAI Lectures*. University of Lucerne (videoconference).
05. 09. 2011	*ShanghAI Lectures*. Lucerne University of Applied Sciences and Arts (videoconference).
11. 08. 2011	*ShanghAI Lectures/Wonderland*. Webinar, University of Zurich / SWITCH.
14. 05. 2011	*The ShanghAI Lectures: A Case Study in Global Education*. Immersive Education Summit, Boston, USA (together with Andreas Schmeil, Beatrice Hasler, Andy Zbinden).
07. 09. 2010	*ShanghAI Lectures*. SWITCHcast Userforum 2010, Bern.
17. 03. 2010	*The ShanghAI Lectures*. 8. VIKTAS-Tag, SWITCH, Zurich.
05. 11. 2008	*Einfluss der Morphologie auf die Fortbewegung*. Workshop «Robotik im Gymnasium», ETH Zurich (together with Dorit Assaf).

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